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Stream Reach Morphology and Macroinvertebrate Community Structure in High-Quality, Cold Water Streams

Publication 189 *August 1997*

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Charles A. McGarrell
Biologist

Water Quality & Monitoring Programs
Susquehanna River Basin Commission

This report is prepared in cooperation with the Pennsylvania Department of Environmental Protection, Bureau of Watershed Conservation, Division of Water Quality Assessment and Standards, under Grant ME95732.

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Stream Reach Morphology and Macroinvertebrate Community Structure in High-Quality, Cold Water Streams

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Biologist

ABSTRACT

Rosgen stream classification and rapid bioassessment data were used to identify relationships between stream reach morphology and the macroinvertebrate communities of high-quality, cold water fisheries (HQ-CWFs) in the Pennsylvania portion of the Susquehanna River Basin. Channel substrate composition, channel entrenchment, and surface water slope were the stream reach morphology variables with the greatest influence on bioassessment metric scores. The data also were used to evaluate the effectiveness of stream order (Strahler method) and Rosgen stream type designation as stream reach classification variables. Rosgen stream classification designation was more effective than stream order at partitioning biological variation among HQ-CWFs. Taxonomic richness and modified percent mayfly index scores were significantly different between Rosgen type B and C streams. A significant difference also was observed between the modified Hilsenhoff index scores of B3 and B4 streams. No significant relationships existed between stream order and bioassessment metric scores. Rosgen classification information also was useful for evaluating the overall physical habitat conditions of HQ-CWFs and identifying streams that had deviated from stable, "natural" morphological conditions.

INTRODUCTION

In an effort to comply with federal antidegradation requirements, the Pennsylvania Department of Environmental Protection (Pa. DEP) developed the Pennsylvania Special Protection Waters Program (Shertzer, 1992). The program, which includes streams or watersheds that exhibit exceptional water quality and other environmental features, protects selected waterways by establishing higher water quality standards than those that typically apply to the surface waters of the commonwealth. Streams and rivers that are being considered for inclusion in the program usually undergo an assessment of their "ecological significance", which is determined based on their EPA Rapid Bioassessment Protocol (RBP) III Score, relative to the score of a comparable reference site. Reference sites represent benchmarks of the best attainable conditions that can be expected for similar streams within a particular ecological region (Barbour and others, 1996). Thus, the delineation of ecological regions and the identification of similar streams and appropriate reference sites are critical components of bioassessment methodology.

Barbour and others (1996) describe the process of characterizing regional reference conditions as consisting of three steps:

1. Classification of streams based on geographic region and stream type;
2. Selection of the best available sites within a given class as candidate reference sites; and
3. Characterization of reference conditions based on biological survey data.

These authors state that the objectives of the first step in this process, the classification of streams based on geographic region and stream type, are to reduce the complexity of biological information and improve the resolution or sensitivity of

biological surveys by partitioning or accounting for variation among sites. Furthermore, they suggest that "the best classification variables are those that are readily obtained from maps or regional water characteristics such as ecoregion, gradient, alkalinity, and hardness." Stream characteristics that are readily affected by human activities or occur as a biological response to physical or chemical conditions (i.e., land use, habitat condition, or nutrient concentrations) should not be used as classification variables.

Barbour's methodology indicates that stream classification should include variables that describe channel features at a variety of different spatial scales such as geographic region and stream type. Gregory and others (1991) described the spatial hierarchy of drainage basins as consisting of channel features from five spatial scales: (1) network; (2) segment; (3) reach; (4) channel unit; and (5) channel subunit (Table 1). However, the actual number and definition of spatial scales utilized in stream classification programs vary and may be dictated by the specific objectives of the program and budgetary and manpower constraints. For example, the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program utilizes a hierarchical stream habitat assessment design that includes characterizing habitat at four spatial scales: (1) basin; (2) stream segment; (3) stream reach; and (4) microhabitat.

Currently, the Pa. DEP classifies streams based on ecoregion (or subregion) and stream order when conducting bioassessments and ecological significance surveys of special protection candidate streams (Shertzer, 1992). Biological (macroinvertebrate) data collected during these surveys is limited to riffle areas. The classification and sampling techniques used by the Pa. DEP effectively incorporate classification variables at the segment and channel unit spatial scales, as described in Table 1, by including ecoregion designation and by limiting biological data collection to riffles. However, stream order, which is used to characterize streams at the reach spatial scale, does not characterize stream reach morphology, which is a critical component of stream ecosystems. Stream reach morphology

Table 1. Spatial Scales Included in the Hierarchical Organization of Drainage Basins (Described by Gregory and others, 1991)

Spatial Scale	Number of Channel Widths	Delineation Features
Network	100,000	Network of fluvial and valley floor landforms within a basin extending from headwaters to large rivers or estuaries
Segment	1,000 - 10,000	Regional landform patterns that reflect different agents of landscape formation (scale of 10 to 100 Km), major topographic discontinuities such as high gradient mountain rivers or low gradient lowland rivers
Reach	10 - 100	Type and degree of local constraint imposed on the channel and valley floor by geomorphic features
Channel Unit	1	Water-surface slope, channel width/depth ratio, extent of turbulent, high-velocity flow; typically classified as riffles, pools, and runs
Channel Subunits	0.1	Local hydraulic features, at scales less than the active channel width, that are created by boulders, logs, or gravel bars and exist at flows less than those required to fill the active channel

influences: (1) instream habitat conditions and hydrograph characteristics; (2) the fluvial development of valley floor landforms such as flood plains, natural levees, and terraces; (3) riparian vegetative communities and the quantity and quality of organic matter entering streams; and ultimately; (4) aquatic biological community structure. For reviews of the influence of morphological conditions on stream and riparian ecosystems, see Vannote and others (1980) and Gregory and others (1991).

The Rosgen Stream Classification System (Rosgen, 1996), which is commonly used by U.S. Department of Agriculture (USDA), Forest Service hydrologists, provides a means by which morphologically similar stream reaches can be identified. This system utilizes morphological variables that allow for the classification and assessment of stream reach morphology at four different levels of resolution. Rosgen level I and II inventories are designed for classifying stream reaches. Level I classification is a coarse-scale geomorphic characterization that can be conducted using information taken from topographic and landform maps and from aerial photographs. Level II classification, based on field data, is a more detailed morphological description that provides a quantitative classification of stream reaches. Rosgen level I and II inventories are summarized in Table 2.

Rosgen level III and IV inventories are very detailed and build upon the information gathered during level I-II inventories. Level III inventories are designed for assessing the existing condition or the "state" of specific stream reaches. Level IV inventories are used for establishing empirical relationships pertaining to the prediction of Manning's "n" values and studying sediment transport processes and hydraulic geometry characteristics of streams based on stream type (as determined from level II data) and stream state (based on level III data). These relationships can then be extrapolated to similar stream reaches for which level IV data are not available.

Table 2. Summary of Rosgen Level I and II Inventories

Rosgen Level I (Geomorphic Characterization)	
Primary Information Sources:	Topographic and landform maps Aerial photography
Delineation Criteria:	Channel slope (valley slope/sinuosity) Channel shape (narrow/deep vs. wide/shallow) Channel patterns (single thread, multiple thread, anastamosed)
Stream Reach Classes:	Stream types "A" through "G"
Rosgen Level II (Morphological Description)	
Primary Information Sources:	Field Data
Delineation Criteria:	Entrenchment ratio Width/depth ratio Sinuosity Channel slope Channel materials
Stream Reach Classes:	Stream types "A1a...A6a" through "G1c...G6c"

To accurately classify candidate and reference streams for the purpose of comparing their macroinvertebrate communities, it is essential that these streams be similar at a variety of spatial scales. The author hypothesizes that the Pa. DEP could strengthen the procedure that is currently used for identifying comparable Special Protection candidate and reference sites by incorporating Rosgen level I or II stream reach classification designation into this procedure. The primary objectives of this project are to evaluate the potential utility of the Rosgen classification system as a method for characterizing HQ-CWFs at the stream reach spatial scale and to identify relationships between benthic macroinvertebrate community structure and stream reach morphology in HQ-CWFs.

METHODS

Field and Laboratory Methods

A total of 35 sample sites located on HQ-CWFs were sampled between September 11 and November 11, 1996 (Figure 1 and Table 3). Sample sites were located in the Pennsylvania portion of the Susquehanna River Basin and represented six ecoregions and 15 subregions (Figure 2). At each sample site, stream reach morphology and chemical water quality conditions were documented in the field, and benthic macroinvertebrate samples were collected for analysis in the laboratory.

Chemical water quality

Field water quality measurements included water temperature, dissolved oxygen, conductivity, pH, alkalinity, and acidity. Dissolved oxygen was measured using a YSI Model 55 dissolved oxygen meter. Conductivity and pH were measured using Cole-Parmer Model 1481-61 and Model 5996-70 meters, respectively. Alkalinity was measured by titrating a known volume of sample water to pH 4.5 with 0.02N H_2SO_4. Acidity was measured by titrating a known volume of sample water to pH 8.3 with 0.02N NaOH.

Benthic macroinvertebrate sampling

Macroinvertebrate communities were sampled using a 0.3 m D-frame kick net to collect organisms dislodged from riffle areas by physical agitation of approximately 0.3 m^2 of the streambed. Two samples were collected at each site, one from an area of high velocity and the other from an area of lower velocity. The two samples were composited and preserved in a solution of isopropyl alcohol and glycerin for laboratory analysis. In the laboratory, 100-organism subsamples were taken from composite samples using a gridded pan and a random numbers table. The organisms contained in the subsamples were identified to genus (except for Chironomidae and Simuliidae) using taxonomic keys by Merrit and Cummins (1996) and Peckarsky and others (1990) and enumerated.

Stream reach morphology

At each sample site (sample reach), stream reach morphological conditions were characterized using Rosgen level II classification data (Rosgen, 1996). Level II classification data consisted of field measurements of channel cross-section dimensions, sinuosity, slope, and the size of channel materials. Channel cross-section dimensions, sinuosity, and slope were determined using a surveying rod, level, and tape measure. At each site, sinuosity, slope, and channel materials were assessed over the entire sample reach. Sample reaches were approximately equal to 20 bankfull channel widths in length. Sample reach end-points were delineated such that reaches started and ended in the same type of channel unit (e.g., head-of-riffle to head-of-riffle).

At each sample site, a stream channel cross-section, located in a relatively straight, representative segment of the sample reach, was surveyed. While surveying cross-sections, bankfull stage was identified using field stage indicators such as those described by Dunne and Leopold (1978), Harrelson and others (1994), and Rosgen (1996). Some of these indicators included: floodplain elevations, the tops of depositional features such as point bars, breaks in

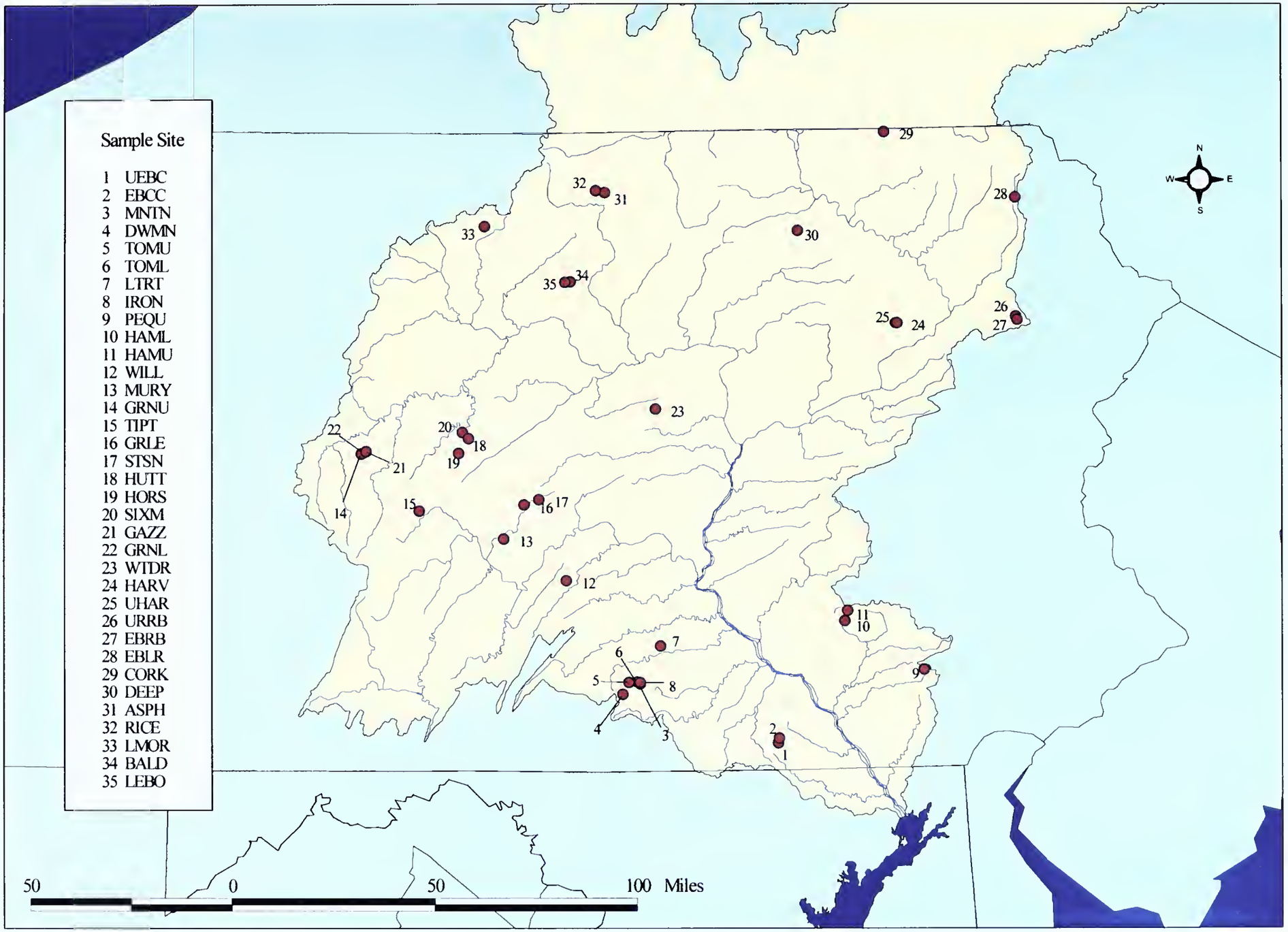

Figure 1. Map Showing the Location of Sample Sites in the Susquehanna River Basin

Table 3. Descriptions of 35 Sample Site Locations

Site Name	Stream Name	7.5 Minute Quadrangle	Latitude	Longitude	Description
ASPH	Asaph Run	Asaph	41.78833	-76.5575	Asaph Run—0.1 mi. upstream of Scotch Pine Hollow confluence
BALD	Baldwin Branch	Slate Run	41.46944	-76.3867	Baldwin Branch—0.5 mi. upstream of Benson Run confluence
CORK	Cork Hill Creek	Forest City	41.98778	-75.9044	Cork Hill Creek—1.5 mi. upstream of Apalachin Creek confluence
DEEP	Deep Hollow	Powell	41.64583	-75.48	Deep Hollow—0.3 mi. upstream of Millstone Creek confluence
DWMN	Dead Woman Hollow	Arendtsville	39.995	-76.6272	Dead Woman Hollow—0.5 mi. upstream of Cumberland/Adams County line
EBCC	E. Br. Codorus Creek	Glen Rock	39.83417	-75.3539	E. Branch Codorus Creek—at Blymire Hollow and Sunlight Drive intersection
EBLR	E. Br. Lackawanna River	Orson	41.74083	-74.5208	E. Branch Lackawanna River—approximately 200 ft. upstream of Route 371 bridge
EBRB	E. Br. Roaring Brook	Sterling	41.30778	-74.5094	E. Branch Roaring Brook—0.2 mi. upstream of Conrail rail line
GAZZ	Gazzam Run	Irvonia	40.86083	-77.4208	Gazzam Run—0.6 mi. upstream form Route 729 bridge.
GRLE	Greenlee Run	McAlevys Fort	40.67278	-76.1708	Greenlee Run—0.1 mi. upstream of Croyle Run confluence
GRNL	Green Run (Lower)	Irvonia	40.85917	-77.4158	Green Run—0.2 mi. upstream of Stony Run confluence
GRNU	Green Run (Upper)	Irvonia	40.85417	-77.4017	Green Run—1.1 mi. upstream of Stony Run confluence
HAML	Hammer Creek (Lower)	Lititz	40.2475	-75.6667	Hammer Creek—0.4 mi. upstream of Walnut Run confluence
HAMU	Hammer Creek (Upper)	Richland	40.28167	-75.68	Hammer Creek—upstream of Distillery Road bridge
HARV	Harveys Creek	Harveys Lake	41.30694	-75.9383	Harveys Creek—0.8 mi. downstream of Bryant Pond
HORS	Horse Hollow	Sandy Ridge	40.85667	-77.8606	Horse Hollow—at the 1,963 ft. elevation Bench Mark
HUTT	Hutton Run	Black Moshannon	40.91028	-77.9056	Hutton Run—0.2 mi. upstream of Route 504 bridge
IRON	Iron Run	Dickinson	40.03722	-76.7117	Iron Run—approximately 150 ft. upstream of Mountain Creek confluence
LEBO	Lebo Run	Young Womans Creek	41.46806	-76.3683	Lebo Run—0.5 mi. upstream of Young Womans Creek confluence
LMOR	L. Moores Run	Austin	41.67389	-77.9803	Little Moores Run—0.1 mi. upstream of Windfall Hollow
LTRT	Letort Spring Run	Carlisle	40.1725	-76.8094	Letort Spring Run—0.3 mi. downstream of Route 34 bridge
MNTN	Mountain Creek	Dickinson	40.03417	-76.7094	Mountain Creek— 0.1 mi. upstream of Iron Run confluence
MURY	Murray Run	Donation	40.55389	-76.0742	Murray Run—2.1 mi. upstream of Center Union
PEQU	Pequea Creek	Honey Brook	40.07	-74.0314	Pequea Creek—0.2 mi. upstream of Cambridge Road Bridge
RICE	Rice Run	Asaph	41.79556	-76.5178	Rice Run—upstream of Baker Branch confluence
SIXM	Sixmile Run	Black Moshannon	40.935	-77.8772	Sixmile Run—0.6 mi. upstream of Munson Road bridge
STSN	Standing Stone Creek	McAlevys Fort	40.69278	-76.2392	Standing Stone Creek—0.2 mi. downstream of the Alan Seegar Natural Area
TIPT	Tipton Run	Tipton	40.65444	-77.6717	Tipton Run—0.3 mi. downstream of Mulligan Hollow confluence
TOML	Toms Run (Lower)	Dickinson	40.03917	-76.6956	Toms Run—0.6 mi. upstream of Route 233 bridge
TOMU	Toms Run (Upper)	Dickinson	40.03722	-76.6539	Toms Run—directly upstream of Camp Michaux
UEBC	UNT to E. Br. Codorus	Glen Rock	39.81583	-75.35	UNT to East Branch Codorus Creek—at T574 and Brillstrick Road intersection
UHAR	UNT to Harveys Creek	Harveys Lake	41.30611	-75.9453	UNT to Harveys Creek—upstream of Route 118
URRB	UNT to Roaring Brook	Sterling	41.31944	-74.5172	UNT to Roaring Brook—upstream of T344 bridge
WILL	Willow Run	McVeytown	40.40333	-76.3686	Willow Run—at State Game Lands Number 215
WTDR	White Deer Creek	Carroll	41.01167	-76.7936	White Deer Creek—0.2 mi. downstream of Black Gap Road

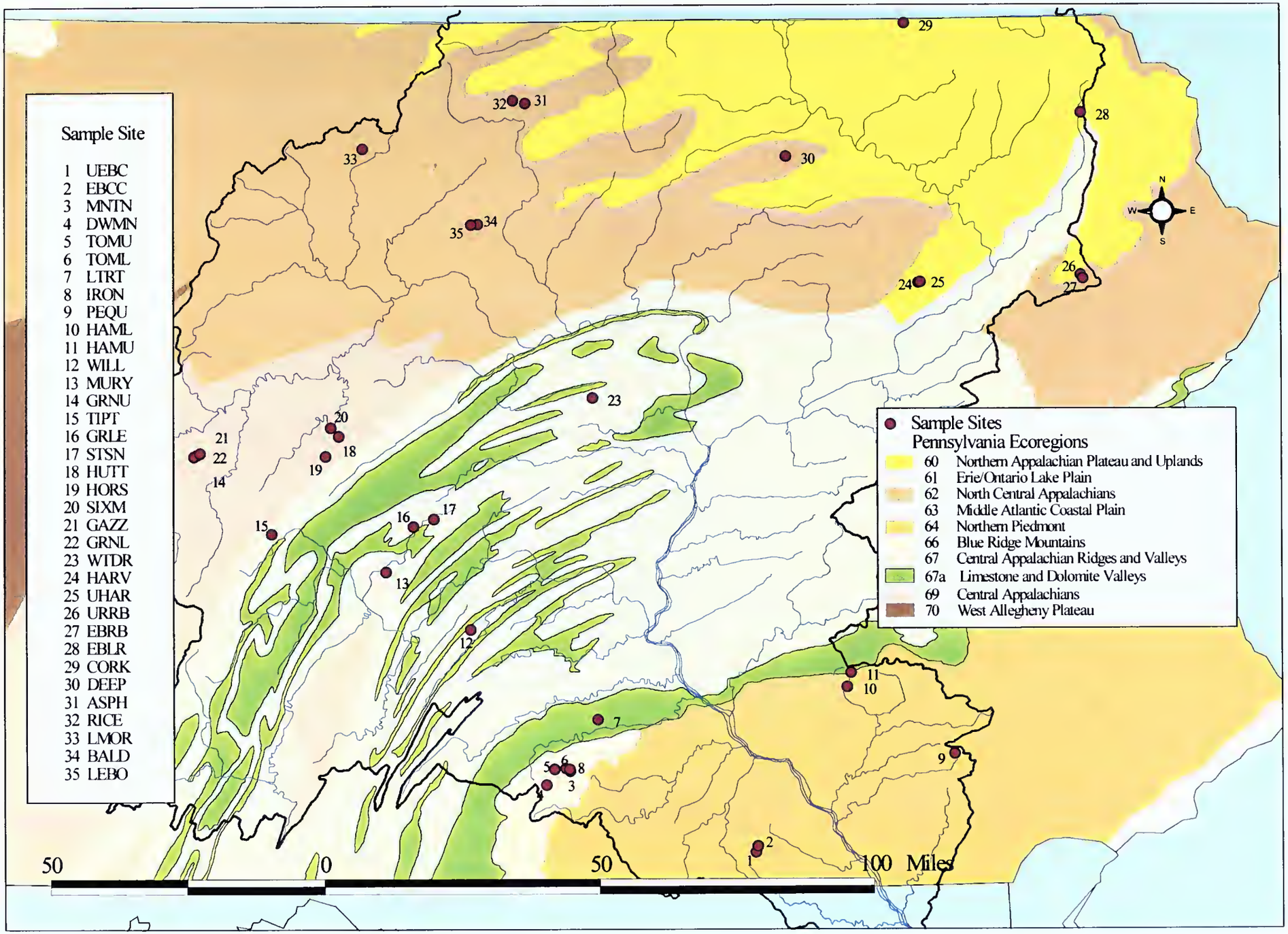

Figure 2. Map Showing the Ecoregions of Pennsylvania and the Location of Sample Sites

streambank slope, changes in streambank particle size, and staining of rocks. Cross-section data were analyzed using XSPRO stream channel cross-section analysis software (Grant and others, 1992) to obtain cross-section dimensions.

Entrenchment and width/depth ratios were derived from channel cross-section data. Entrenchment ratio describes the vertical containment of the stream channel (the degree to which it is incised in the valley floor). Entrenchment ratio was calculated as the ratio of the width of the flood-prone area to the surface width of the bankfull channel. The flood-prone area width was measured at the elevation that corresponded to twice the maximum depth of the bankfull channel (Figure 3). Width/depth ratio was calculated as the ratio of the bankfull surface width to the mean depth of the bankfull channel.

Sinuosity was calculated as the ratio of stream channel length to valley length of the study reach. Stream length was determined in the field by measuring the length of each channel unit (riffle, run, or pool) in the study reach using a tape measure extended in alignment with the channel thalweg. Valley length was determined by measuring the straight line distance between the upstream and downstream end-points of the reach, which were surveyed in the field and plotted in the office. Water surface slope was calculated as the change in surface water elevation per unit stream length. Surface water elevation at the upstream and downstream end-points of each study reach were surveyed in the field. Stream length was determined in the field using a tape measure, as described above.

Dominant channel materials were determined based on the particle size distribution of bankfull channel materials using the modified Wolman "pebble-count" method, as described by Rosgen (1996). The intermediate axis diameter of approximately 100 randomly selected substrate particles was measured and tabulated in the field. The number of particles selected from a given channel unit (riffle, run, or pool) was based on the channel unit configuration of the stream reach, such that channel units were sampled in proportion to their occurrence in the reach. The dominant particle size of the stream reach was determined as the indexed d_{50} value from a cumulative percent plot of the pebble count data (Appendix A). Rosgen level II stream type designations were determined using the criteria summarized in Table 4.

Ecoregion designation, stream order, and watershed characteristics

Sample site ecoregion (subregion) designation and watershed characteristics (e.g., drainage area, percent ecoregion composition) were determined using PC ArcView spatial analyst geographic information system (GIS) software and readily available geographic data. Stream order (Strahler method) was delineated from United States Geological Survey 7.5 minute quadrangle maps. Intermittent streams were not included in stream order designations.

Data Analysis

All statistical tests and simple linear correlation analyses were conducted in accordance with Zar (1984) using MINITAB statistical software (MINITAB, 1996). Box-and-whisker plots were generated using this same software. Significant results were reported at the 95 percent confidence level ($p<0.05$). When statistically significant analysis of variance (ANOVA) results were obtained, differences among the sample groups were evaluated using Tukey multiple comparison tests and box-and whisker plots. Box-and-whisker plots graphically display the median, minimum, maximum, 25th and 75th percentiles (also referred to as the 1st and 3rd quartiles, respectively), and outliers of a given sample group. Box-and-whisker outliers are points outside of the lower and upper limits of the sample group. Sample group limits were determined as follows:

Lower Limit:	1st quartile - 1.5 (3rd quartile - 1st quartile)
Upper Limit:	3rd quartile - 1.5 (3rd quartile - 1st quartile)

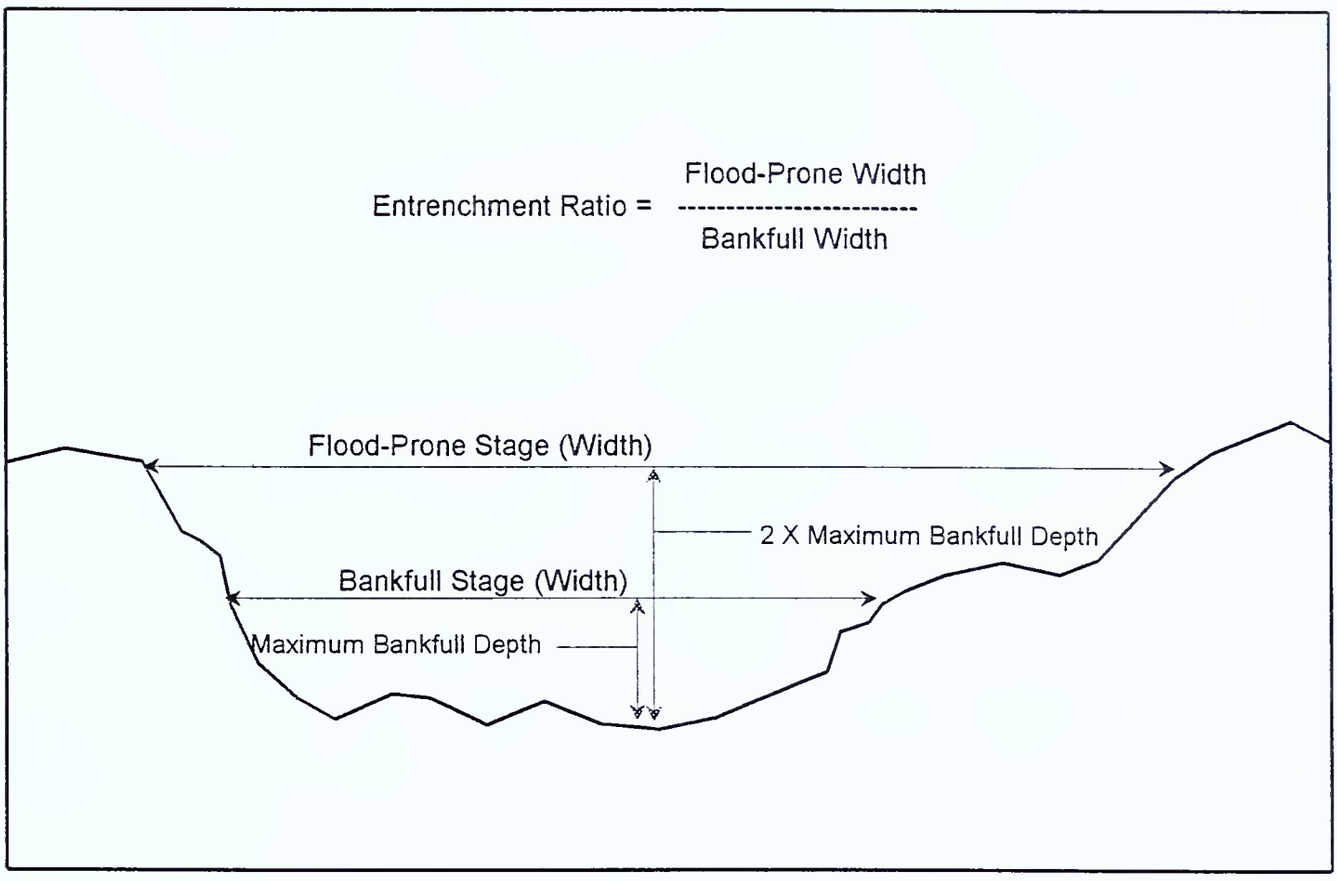
Entrenchment Ratio = Flood-Prone Width / Bankfull Width
Flood-Prone Stage (Width)
2 X Maximum Bankfull Depth
Bankfull Stage (Width)
Maximum Bankfull Depth

Figure 3. Illustration of Entrenchment Ratio Calculated From Bankfull and Flood-Prone Channel Widths

Table 4. Key Used for Rosgen Level I and II Classification of Sample Sites

	SINGLE-THREAD CHANNELS														MULTIPLE CHANNELS			
Entrenchment Ratio*	ENTRENCHED (Ratio: <1.4)						MODERATELY ENTRENCHED (Ratio: 1.4 - 2.2)			SLIGHTLY ENTRENCHED (Ratio: >2.2)					↓ ↓ ↓		↓ ↓ ↓	
Width/Depth Ratio *	LOW Width/Depth (<12)				Moderate to HIGH Width/Depth (>12)		MODERATE Width/Depth (>12)			VERY LOW Width/Depth (<12)		Moderate to HIGH Width/Depth (>12)			VERY HIGH Width/Depth (>40)			LOW W/D (<40)
Sinuosity*	LOW SINUOSITY (<1.2)		MODERATE SINUOSITY (>1.2)		MODERATE SINUOSITY (>1.2)		MODERATE SINUOSITY (>1.2)			VERY HIGH SINUOSITY (>1.5)		HIGH SINUOSITY (>1.2)			LOW SINUOSITY (<1.2)			Low-Hi Sinuosity (1.2 - 1.5)
Stream Type	A		G		F		B			E		C			D			DA
Slope	Slope Range		Slope Range		Slope Range		Slope Range			Slope Range		Slope Range			Slope Range			Slope
	>0.10	004 - 0.099	0.02 - 0.039	<0.02	0.02 - 0.039	<0.02	0.04 - 0.099	0.02 - 0.039	<0.02	0.02 - 0.039	<0.02	0.02 - 0.039	0.001 - 0.02	<0.001	0.02 - 0.039	0.001 - 0.02	<0.001	<0.005
Channel Material																		
Bedrock	A1a+	A1	G1	G1c	F1b	F1	B1a	B1	B1c			C1b	C1	C1c				
Boulder (256-4096 mm)	A2a+	A2	G2	G2c	F2b	F2	B2a	B2	B2c			C2b	C2	C2c				
Cobble (64-256 mm)	A3a+	A3	G3	G3c	F3b	B3	B3a	B3	B3c	E3b	E3	C3b	C3	C3c	D3b	D3		
Gravel (2-64 mm)	A4a+	A4	G4	G4c	F4b	F4	B4a	B4	B4c	E4b	E4	C4b	C4	C4c	D4b	D4	D4c	DA4
Sand	A5a+	A5	G5	G5c	F5b	F5	B5a	B5	B5c	E5b	E5	C5b	C5	C5c	D5b	D5	D5c	DA5
Silt/Clay	A6a+	A6	G6	G6c	F6b	F6	B6a	B6	B6c	E6b	E6	C6b	C6	C6c	D6b	D6	D6c	DA6

*Values of ***Entrenchment Ratio*** and ***Sinuosity*** can vary by +/-0.2 units; values for ***Width/Depth Ratio*** can vary by+/- 2.0 units. Source: Modified from Rosgen (1996).

Detrended correspondence analysis (DCA) was used to reveal outliers in the data set based on macroinvertebrate taxa abundance. Gauch (1982) describes outliers as peculiar samples whose relationships to other samples in the data set are not expressed by the information in the data. Furthermore, this author states that, in general, outliers tend to compress the other samples in the data set into an undesirably small area of the ordination and obscure the analysis of the data set as a whole, and thus, should be deleted from the data set. Since the focus of this study is on the relationships between stream reach morphology and the benthic macroinvertebrate communities of HQ-CWFs, samples that were primarily influenced by water quality conditions or that had obviously degraded channel morphology or macroinvertebrate communities were removed from the analysis. DCA ordinations were produced using software developed by Kovach (1993). Rare taxa, those present at less than 5 percent of the sites, were removed prior to running ordination analyses (Gauch, 1982).

Five metrics were used to describe sample site benthic macroinvertebrate communities. These metrics, which included taxa richness, modified EPT index, modified Hilsenhoff index, percent dominant taxa, and modified percent mayfly index, are summarized in Table 5. The Pa. DEP was considering this suite of metrics for assessing the ecological significance of Special Protection candidate-streams at the start of this project (Pa. DEP, Unpublished).

RESULTS

Data Summary and the Identification of Outliers

Rosgen level I classification delineates the 35 sample sites included in this study into five different stream types. The majority of the sample sites are either B or C stream types, which together account for 80 percent of the sites included in the study. Rosgen level II stream classification further delineates the 35 sample sites into 13 different stream types consisting primarily of types B4c (20 percent), C3 (14 percent), C4b (11 percent), and C4 (11 percent) (Figure 4). Rosgen stream reach classification information is summarized in Table 6. Stream channel morphology and water quality data are listed in Appendixes A and B.

Table 5. Summary of the Bioassessment Metrics Used to Describe Sample Site Benthic Macroinvertebrate Communities

Metric	Description
Taxa Richness	Total number of different taxa.
Modified EPT Index	Number of pollution intolerant (Hilsenhoff tolerance value < 5) Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly) taxa
Modified Hilsenhoff Index	Hilsenhoff index of pollution tolerance with pollution tolerance values modified for Pennsylvania
Percent Dominant Taxa	Relative abundance of the dominant taxa expressed as percent of the 100-organism subsample
Modified Percent Mayfly Index	Relative abundance of pollution intolerant (Hilsenhoff tolerance value < 5) mayflies expressed as percent of the 100-organism subsample

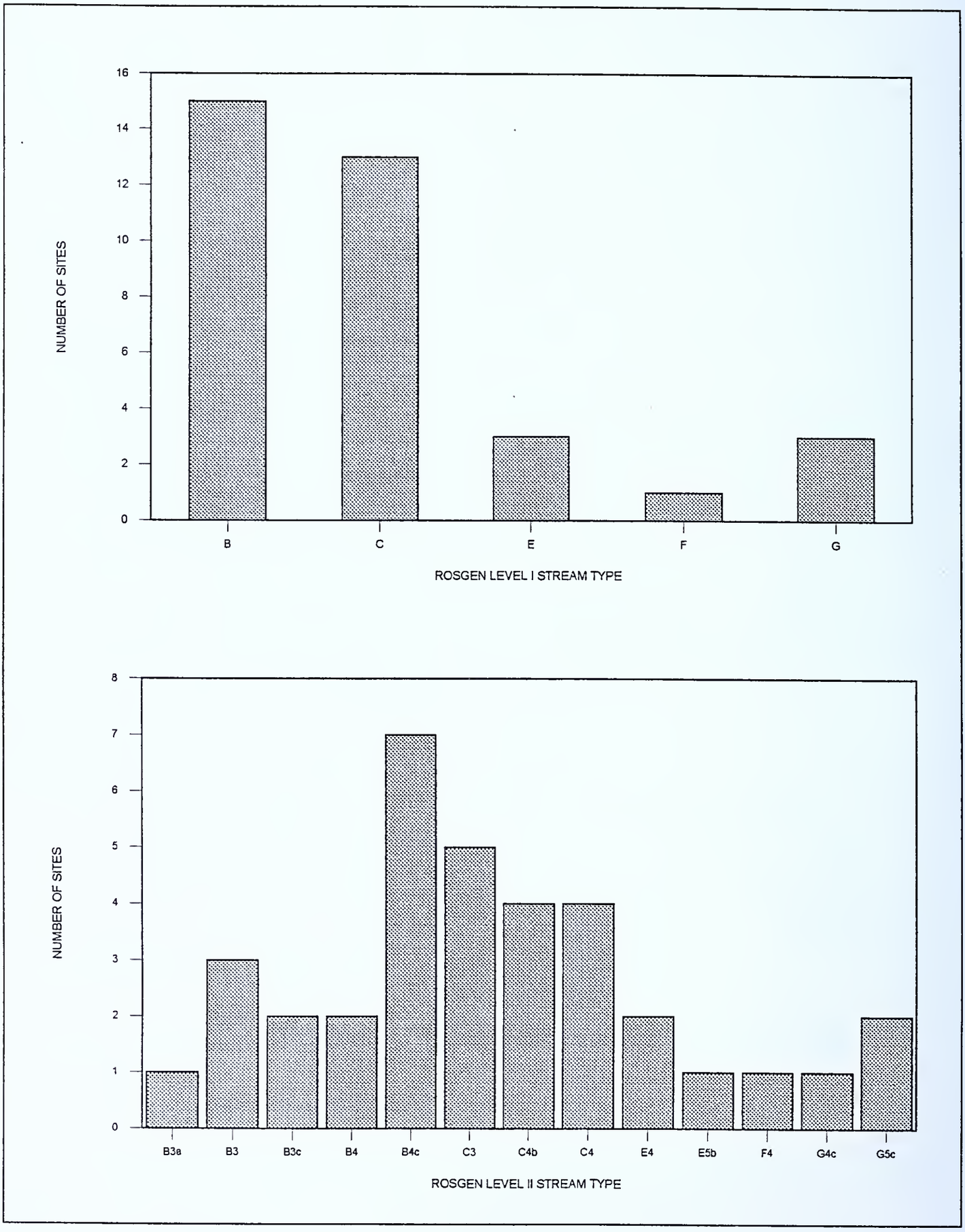

Figure 4. Histograms of Rosgen Level I and II Classification Results of 35 Sample Sites

Table 6. Summary of Rosgen Stream Reach Classification Data of 35 Sample Sites

Sample Site	Entrenchment	W/D Ratio	Sinuosity	Slope	Channel Material (d_{50})	Rosgen Level I Class	Rosgen Level II Class	Stream Order 1:24,000
ASPH	1.8	28	1.1	0.020	Cobble	B	B3	3
BALD	1.4	30	1.1	0.029	Cobble	B	B3	2
CORK	2.0	22	1.2	0.019	Gravel	B	B4	1
DEEP	1.4	25	1.1	0.036	Cobble	B	B3	1
DWMN	4.5	22	1.4	0.029	Gravel	C	C4b	2
EBCC	1.7	13	1.0	0.002	Gravel	B	B4c	3
EBLR	3.8	16	1.0	0.010	Cobble	C	C3	2
EBRB	1.3	17	1.0	0.019	Cobble	B	B3c	2
GAZZ	1.4	26	1.4	0.008	Gravel	B	B4c	3
GRLE	4.5	14	1.4	0.014	Cobble	C	C3	1
GRNL	1.3	27	1.5	0.014	Gravel	B	B4c	2
GRNU	1.3	31	1.1	0.012	Gravel	B	B4c	2
HAML	1.3	20	1.1	0.003	Gravel	F	F4	3
HAMU	1.7	11	1.0	0.003	Sand	G	G5c	2
HARV	2.0	23	1.2	0.005	Gravel	B	B4c	2
HORS	4.5	8	1.2	0.025	Sand	E	E5b	1
HUTT	2.8	14	1.1	0.040	Gravel	C	C4b	2
IRON	4.5	21	1.1	0.019	Gravel	C	C4	2
LEBO	2.9	25	1.2	0.015	Cobble	C	C3	3
LMOR	2.0	17	1.2	0.027	Gravel	B	B4	2
LTRT	1.7	14	1.1	0.006	Sand	G	G5c	1
MNTN	4.5	14	1.1	0.005	Gravel	C	C4	3
MURY	1.9	16	1.0	0.014	Gravel	B	B4c	1
PEQU	1.6	16	1.0	0.017	Gravel	B	B4c	2
RICE	2.3	14	1.2	0.040	Gravel	C	C4b	1
SIXM	2.8	21	1.0	0.016	Cobble	C	C3	3
STSN	4.5	15	1.2	0.009	Cobble	C	C3	3
TIPT	1.6	26	1.1	0.010	Cobble	B	B3c	2
TOML	4.5	7	1.0	0.001	Gravel	E	E4	1
TOMU	2.4	33	1.1	0.020	Gravel	C	C4b	1
UEBC	2.0	8	1.2	0.014	Gravel	G	G4c	2
UHAR	1.4	23	1.1	0.041	Cobble	B	B3a	1
URRB	3.6	17	1.1	0.018	Gravel	C	C4	2
WILL	4.5	18	1.2	0.005	Gravel	C	C4	1
WTDR	4.5	11	1.3	0.004	Gravel	E	E4	2

A total of 83 taxa from 43 families were included in the macroinvertebrate data collected at the 35 sample sites (Appendix C). Figure 5 shows the DCA ordination of sample sites based on macroninvertebrate taxa abundance (data set 1). This ordination suggests LTRT, HAMU, HAML, WILL, HORS, HUTT, and HARV may be outliers in the data set. Correlation analysis of channel morphology and water quality data with sample site DCA ordination scores suggests that macroinvertebrate community structure is primarily influenced by conductivity ($r = 0.775$, $p < 0.001$) and alkalinity ($r = 0.737$, $p < 0.001$), and to a lesser extent, degraded channel substrate (Figure 6). LTRT, HAMU, HAML, WILL, HORS, and HUTT were determined to be outliers based on the rationale described in Table 7. HARV was retained since it: (1) is not influenced by limestone geology; (2) is characterized by stable, natural stream reach morphology; and (3) supports a healthy macroinvertebrate community.

A second data set (data set 2), consisting of 29 sites, was constructed by removing the six outliers mentioned above from the original data set of 35 sites. DCA performed on data set 2 produced a DCA ordination of 29 sample sites that does not suggest the presence of any additional outliers (Figure 7). Correlation analysis of DCA axis scores, morphological characteristics, and water quality data indicate that macroinvertebrate community structure in data set 2 is predominantly influenced by dissolved oxygen, percent cobble substrate, acidity, and percent riffle. The metric scores of sample sites are listed in Table 8. The metric scores of data set 1 (35 sites) and data set 2 (29 sites, outliers identified by DCA removed) are summarized in Table 9 and Figure 8.

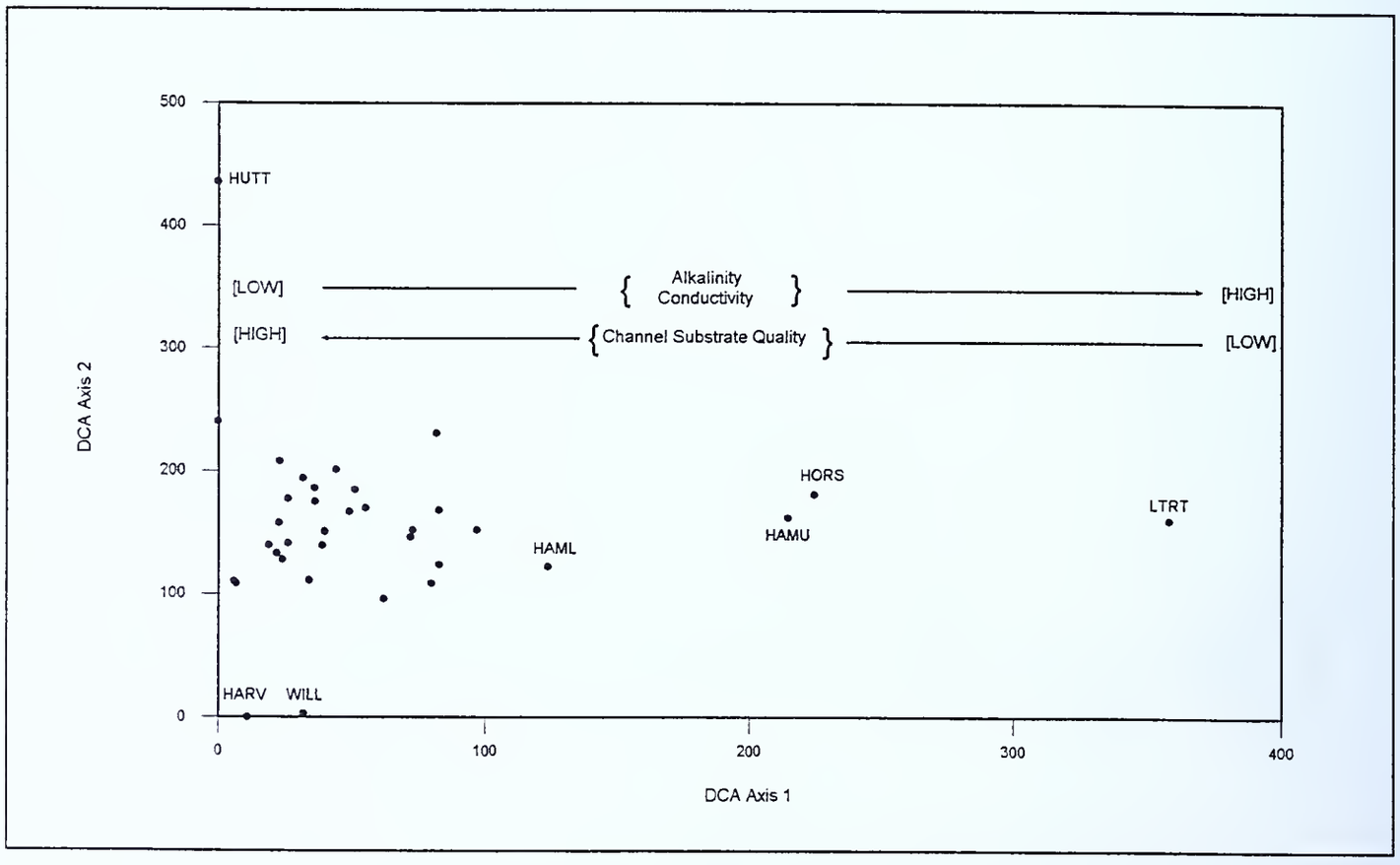

Figure 5. Detrended Correspondence Analysis (DCA) Ordination of 35 Sample Sites Based on Macroinvertebrate Taxonomic Abundance

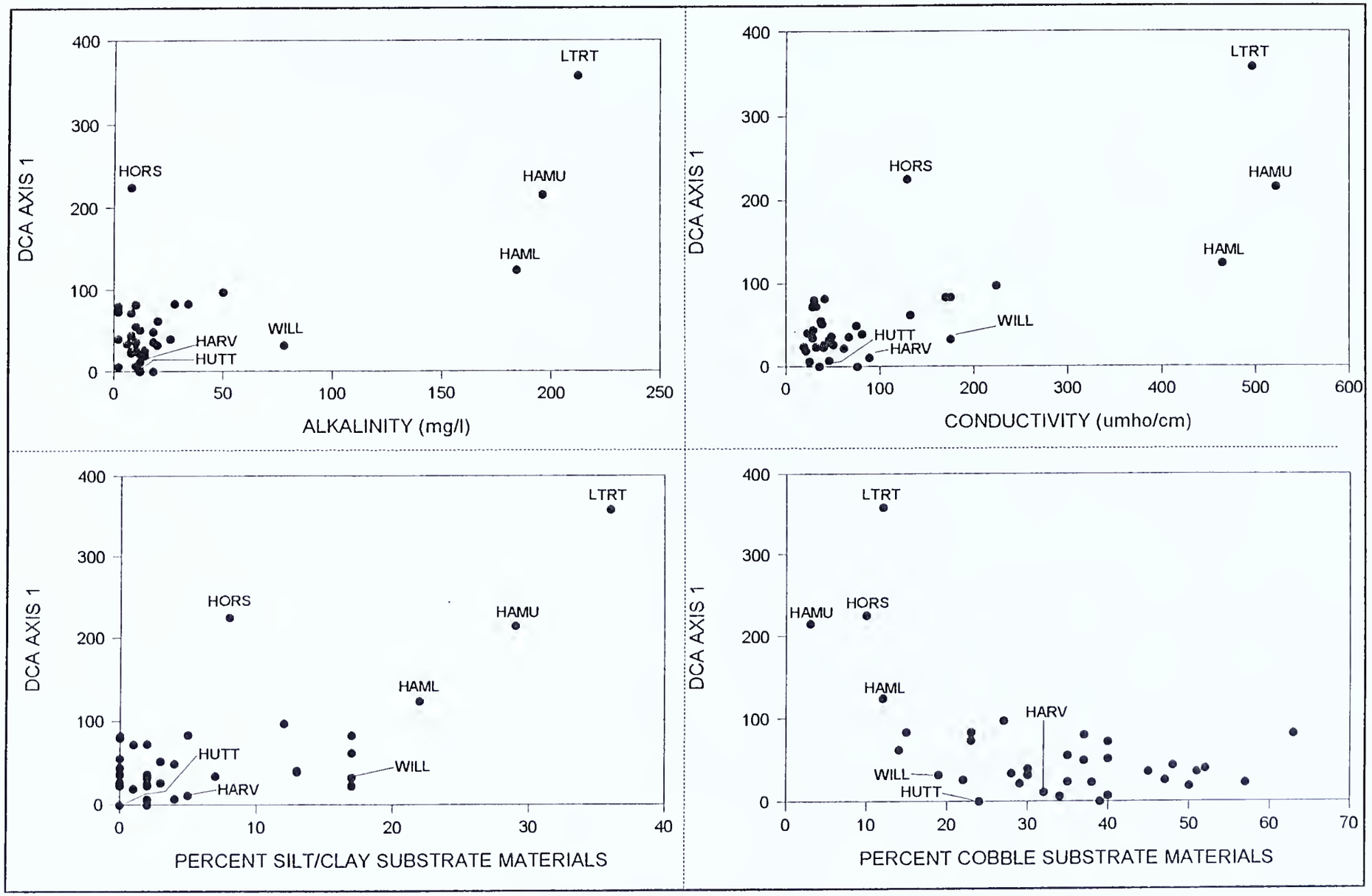

Figure 6. Scatter Diagrams of DCA Axis 1 Scores Vs. the Water Quality and Channel Morphology Parameters Most Strongly Correlated With the DCA Axis 1 Scores of 35 Sample Sites

Table 7. Summary of the Six Outlier Sample Sites and the Justification for Their Removal From the Original Data Set of 35 Sample Sites

Site	Justification for Removal From Data Set
LTRT	Elevated conductivity and alkalinity, geochemically influenced Site is located in, and entire watershed consists of, Ecoregion 67a (limestone or dolomite valleys subregion) Degraded channel morphology (G5c stream type in disequilibrium)
HAMU	Elevated conductivity and alkalinity, geochemically influenced Site is located in, and 51 percent of its watershed consists of, Ecoregion 67a (limestone or dolomite valleys subregion) Degraded channel morphology (G5c stream type in disequilibrium)
HAML	Elevated conductivity and alkalinity, geochemically influenced 60 percent of the site's watershed consists of Ecoregion 67a (limestone or dolomite valleys subregion) Degraded channel morphology (F4 stream type in disequilibrium)
WILL	Elevated conductivity and alkalinity, geochemically influenced 12 percent of the site's watershed consists of Ecoregion 67a (limestone or dolomite valleys subregion)
HORS	Degraded channel substrate composition (52 percent sand) Poor metric scores
HUTT	Poor metric scores

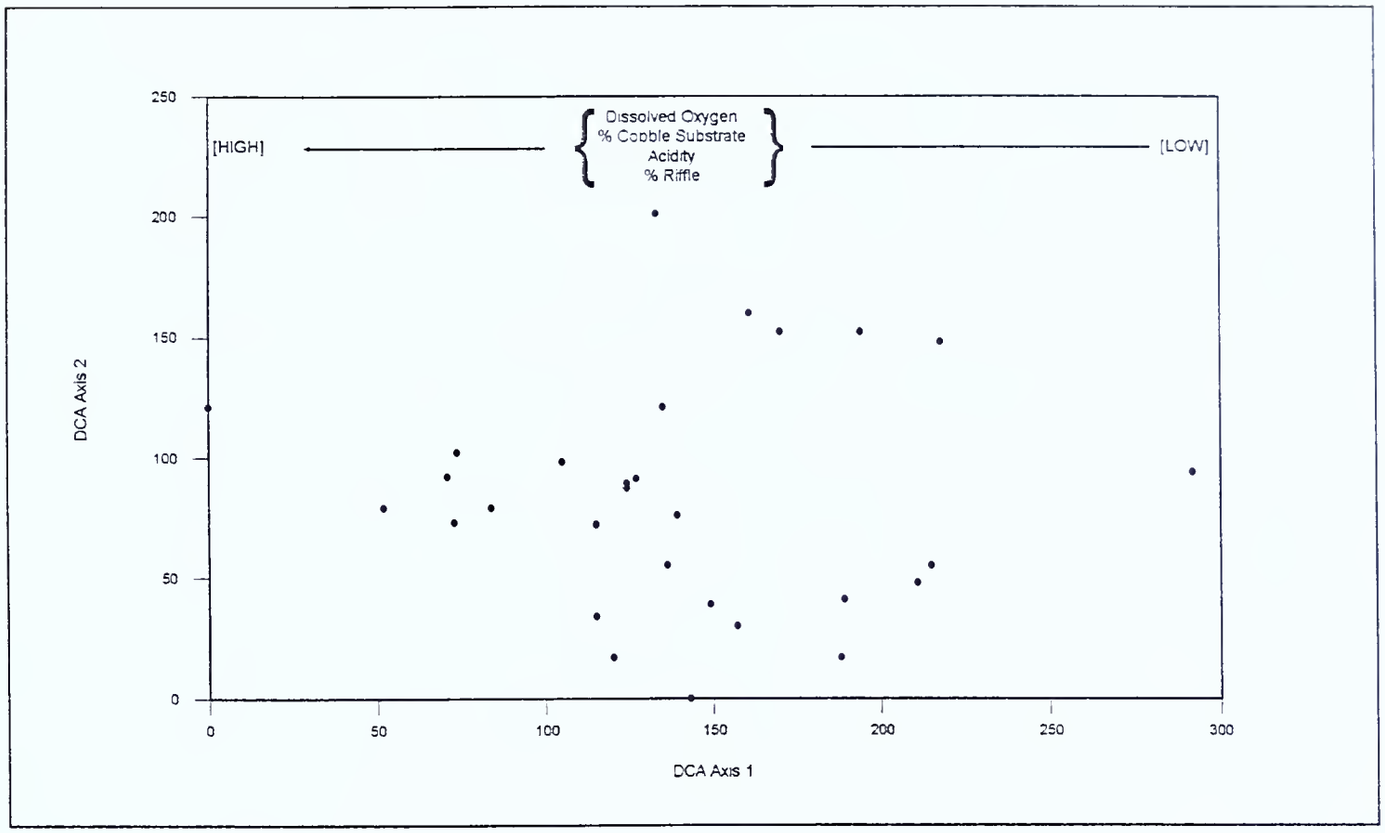

Figure 7. ***DCA Ordination of Data Set 2 Sample Sites*** *(Data set 2 consists of 29 sites and was constructed by removing the six outliers, identified by DCA, from the original data set of 35 sample sites (data set 1).)*

Table 8. Metric Scores of 35 Sample Sites

Site	Tax Rich	Mod EPT	Mod Hils	% Dom	Mod % May
ASPH	25	15	2.37	21	21
BALD	19	10	2.28	16	15
CORK	16	11	1.66	27	36
DEEP	24	15	1.52	25	25
DWMN	7	4	2.81	29	0
EBCC	17	10	3.43	29	25
EBLR	20	12	2.48	19	44
EBRB	28	16	1.98	13	20
GAZZ	25	9	3.75	14	10
GRLE	13	5	3.10	24	8
GRNL	22	12	3.00	18	15
GRNU	20	10	2.80	16	22
HAML*	10	4	4.28	41	10
HAMU*	10	2	5.52	31	1
HARV	16	10	3.32	20	42
HORS*	3	0	7.07	79	0
HUTT*	5	3	1.68	48	48
IRON	21	10	2.69	15	3
LEBO	19	13	2.91	27	12
LMOR	23	12	3.56	16	18
LTRT*	7	0	6.54	56	0
MNTN	21	12	3.58	20	16
MURY	20	9	3.00	21	17
PEQU	19	8	3.72	49	7
RICE	14	11	2.07	22	15
SIXM	17	9	2.70	21	3
STSN	17	9	2.38	29	2
TIPT	21	11	2.31	37	10
TOML	16	7	3.41	12	3
TOMU	17	10	2.77	13	2
UEBC	17	7	2.86	22	9
UHAR	15	10	3.08	21	23
URRB	20	11	2.41	20	14
WILL*	20	10	3.23	27	45
WTDR	22	13	2.44	15	5

* Outlier

Table 9. Summary of Metric Scores of Data Sets 1 (35 Sample Sites) and 2 (29 Sample Sites, 6 Outliers Identified by DCA Removed)

	Taxonomic Richness		Modified EPT Index		Modified Hilsenhoff Index		Percent Dominant Index		Modified Percent Mayfily Index	
Data Set	1	2	1	2	1	2	1	2	1	2
Number of Sites	35	29	35	29	35	29	35	29	35	29
Minimum	3	7	0	4	1.52	1.52	12	12	0	0
Maximum	28	28	16	16	7.07	3.75	79	49	48	44
Mean	17.3	19.0	9.1	10.4	3.10	2.80	26.1	21.8	15.6	15.2
Median	19.0	19.0	10.0	10.0	2.90	2.80	21.0	21.0	14.0	15.0

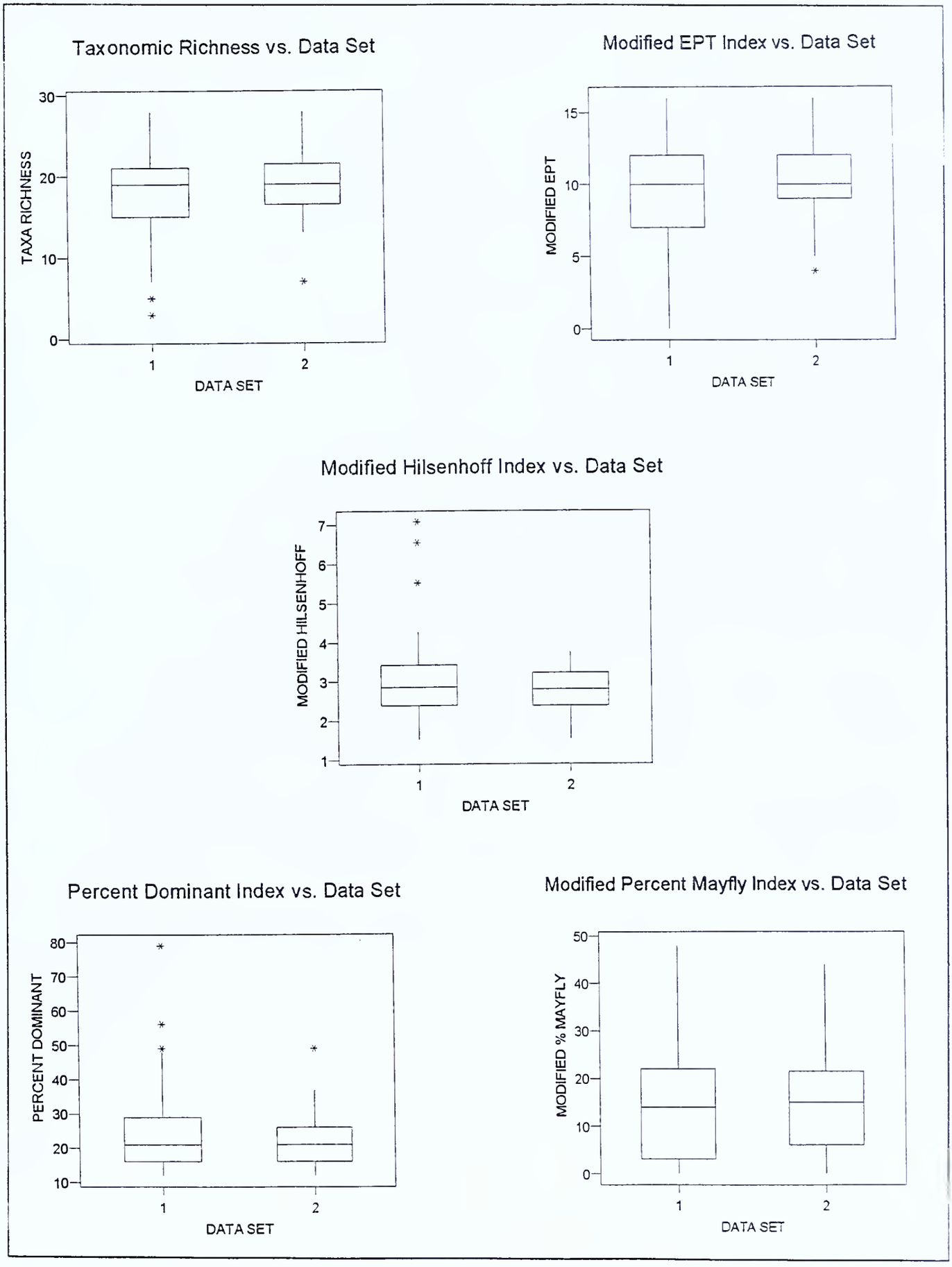

Figure 8. Summary of Metric Scores of Data Sets 1 (35 Sample Sites) and 2 (29 Sample Sites, 6 Outliers Identified by DCA Removed)

Relationships Between Rosgen Classification and Metric Scores and Between Stream Order and Metric Scores

Twenty-six of the 29 sample sites included in data set 2 are classified as Rosgen level I type B or C streams. These 26 sites were used to evaluate the effectiveness of stream order and Rosgen stream type designation as stream reach classification variables (data set 3). The results of statistical analyses to test for significant differences in the metric scores of 1st and 2nd order streams vs. 3rd order streams and between type B vs. type C streams are summarized in Table 10. These analyses indicate that there is a significant difference in the mean taxonomic richness and modified percent mayfly metric scores of Rosgen level I type B and type C streams and that there is no significant difference in any of the metric scores of 1st and 2nd order streams vs. 3rd order streams. Metric scores of data set 3 sample sites, based on stream order and level I stream type designation, are summarized in Figure 9.

Rosgen level II classification refines the major stream types (types A through G) into subcategories based on channel materials and water surface slope. For example, a level II B3c stream reach is a B stream type with cobble substrate and a surface water slope of less than 0.020. Rosgen level II classification of data set 3 sample sites separates these 26 type B and C streams into eight different level II stream types. Due to the excessive fragmentation of the data set and the low number of streams in many of the level II stream type categories, level II classification results did not support further investigation into the relationships between level II stream types and macroinvertebrate community structure. However, excluding the surface water slope subcategory designation and classifying sample sites based on major stream type category and channel materials partitions the 26 type B and C sites into one of four "modified level II" stream type categories (Figure 10).

ANOVA results indicate that modified Hilsenhoff index is the only metric with scores that are significantly different among the four modified level II stream types (Table 11 and Figure 11). Tukey multiple comparison test results indicate that mean Hilsenhoff scores of B3 steams are significantly different than those of B4 streams, but that there is no significant difference among mean Hilsenhoff scores of B3, C3, and C4 or among B4, C3, and C4 streams.

Table10. Summary of F-Test of Sample Variances and t-Tests of Sample Means to Test for Significant Differences in the Metric Scores of Data Set 3 Sample Sites Based on Stream Order and Rosgen Level I Stream Type Designation

Parameter	F-Test: Two-Sample for Variances		t-Test: Two-Sample Assuming Equal Variances		
	$F_{calculated}$	$F_{critical}$	$t_{calculated}$	$t_{critical}$	P(T<=t) two-tail
Type B vs. Type C Streams					
Taxa Richness	1.22	$F_{0.05(2),10,14} = 3.15$	**2.366***	$t_{0.05(2),24} = 2.064$	**0.026**
Modified EPT	1.40	$F_{0.05(2),10,14} = 3.15$	1.521	$t_{0.05(2),24} = 2.064$	
Modified Hilsenhoff Index	3.28	$F_{0.05(2),14,10} = 3.55$	0.275	$t_{0.05(2),24} = 2.064$	
% Dominant Taxa	3.39	$F_{0.05(2),14,10} = 3.55$	0.354	$t_{0.05(2),24} = 2.064$	
Modified % Mayfly	1.77	$F_{0.05(2),10,14} = 3.15$	**2.237***	$t_{0.05(2),24} = 2.064$	**0.035**
1st and 2nd Order vs. 3rd Order Streams					
Taxa Richness	1.62	$F_{0.05(2),18,6} = 5.20$	-0.751	$t_{0.05(2),24} = 2.064$	
Modified EPT	1.38	$F_{0.05(2),18,6} = 5.20$	-0.530	$t_{0.05(2),24} = 2.064$	
Modified Hilsenhoff Index	1.10	$F_{0.05(2),18,6} = 5.20$	-1.357	$t_{0.05(2),24} = 2.064$	
% Dominant Taxa	2.50	$F_{0.05(2),18,6} = 5.20$	-0.235	$t_{0.05(2),24} = 2.064$	
Modified % Mayfly	2.09	$F_{0.05(2),18,6} = 5.20$	0.966	$t_{0.05(2),24} = 2.064$	

* $p<0.05$

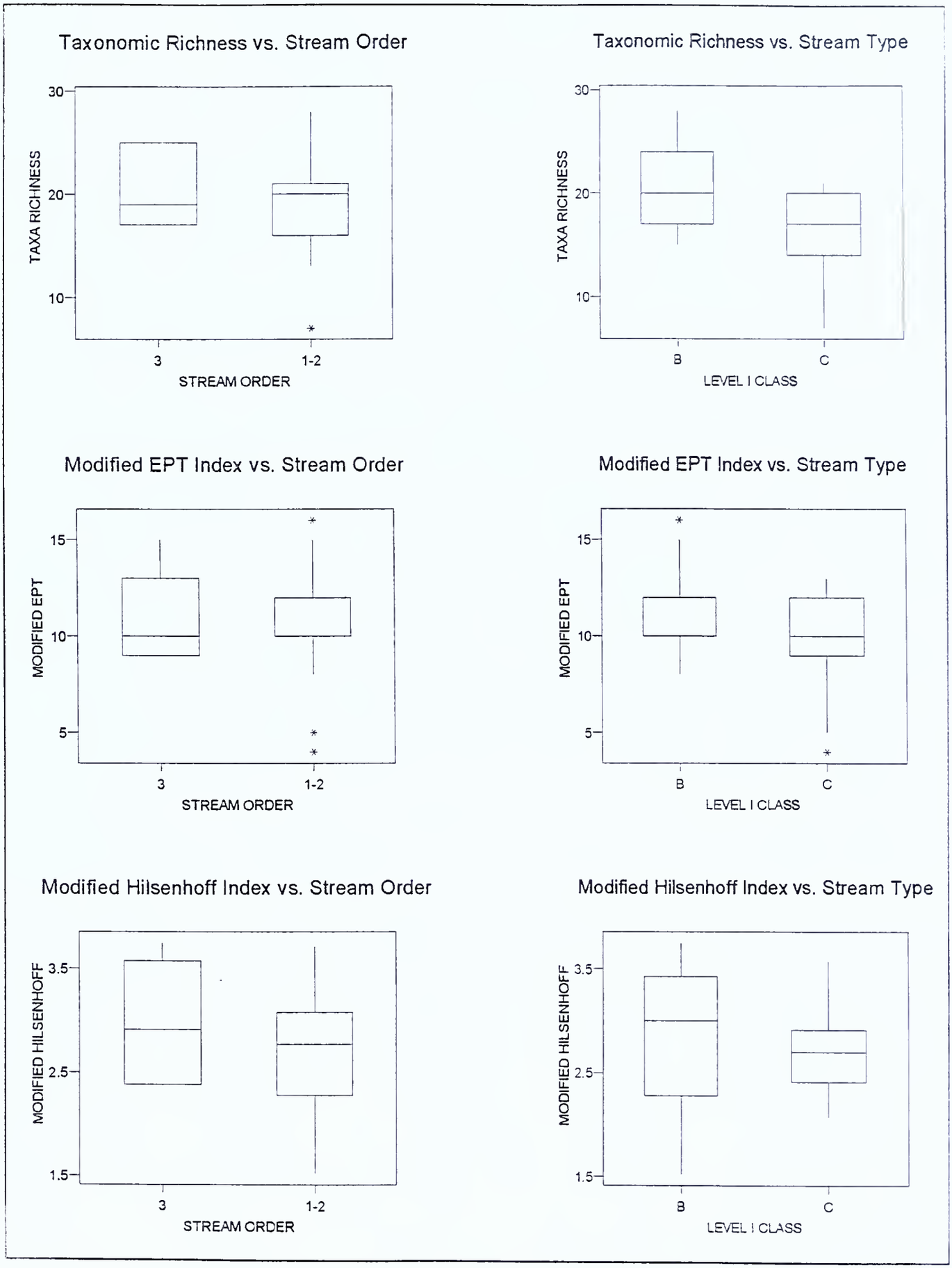

Figure 9. Summary of Data Set 3 Metric Scores Based on Stream Order and Rosgen Level I Stream Type Designation

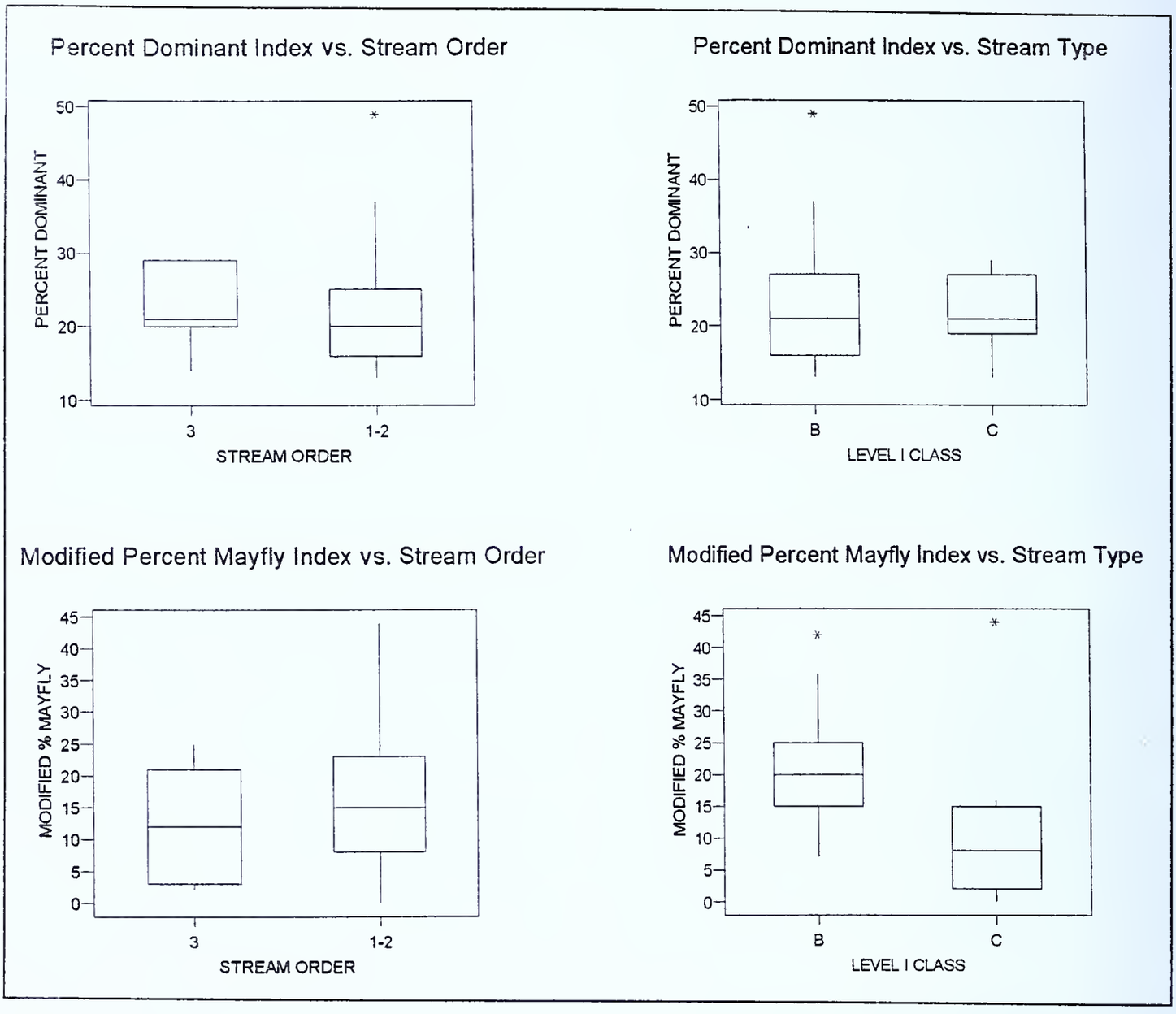

Figure 9. Summary of Data Set 3 Metric Scored Based on Stream Order and Rosgen Level I Stream Type Designation—Continued

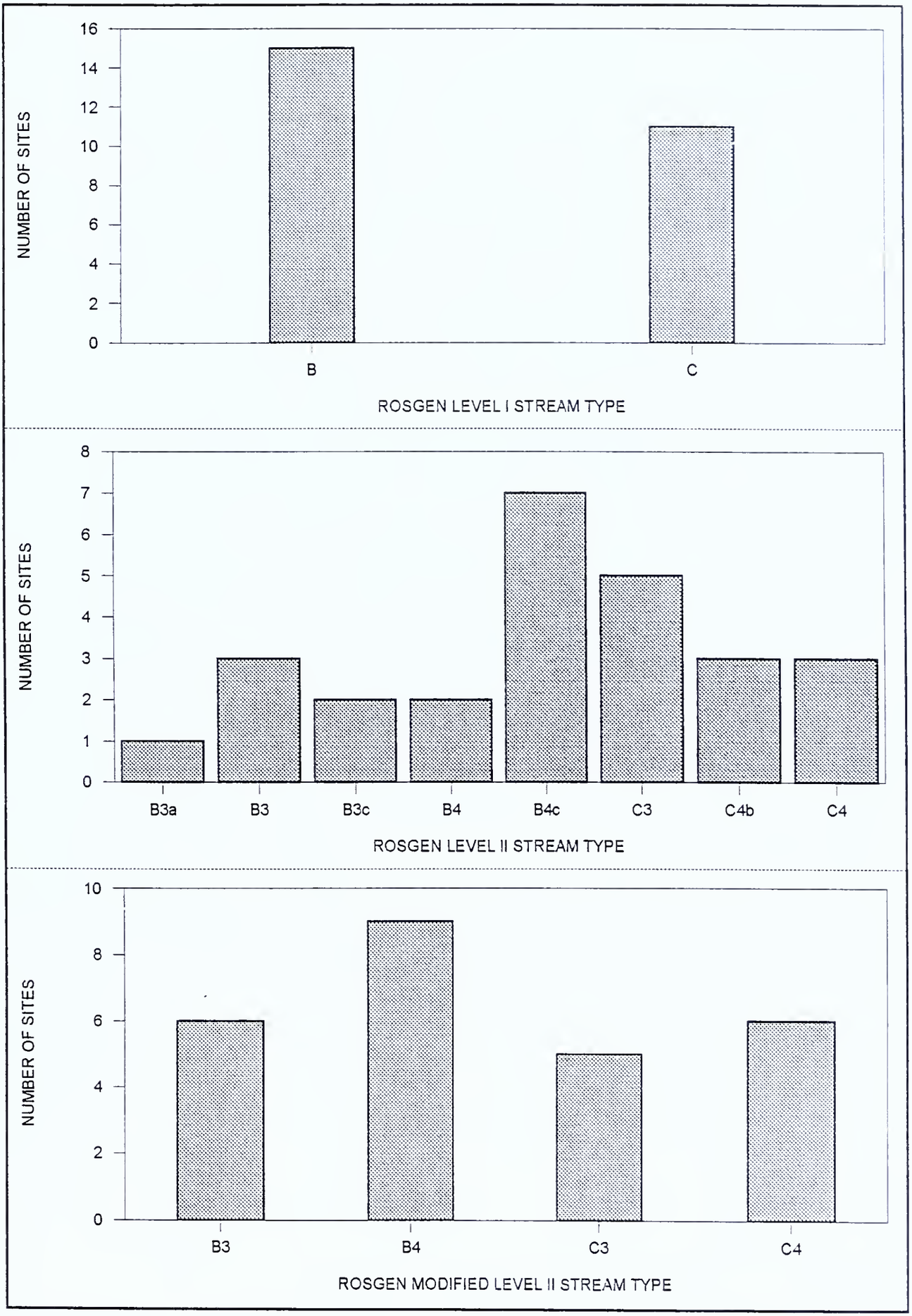

Figure 10. Histograms of Data Set 3 Sample Sites Based on Rosgen Level I, Level II, and Modified Level II Stream Type Designation

Table 11. ANOVA Results of Metric Scores of Modified Level II Stream Types

Source of Variation	SS	df	MS	F	P-value	F crit
Single Factor ANOVA of Taxa Richness Scores						
Between Groups	108.157	3	36.052	2.169	0.120	3.049
Within Groups	365.689	22	16.622			
Total	**473.846**	**25**				
Single Factor ANOVA of Modified EPT Index Scores						
Between Groups	42.206	3	14.069	2.305	0.105	3.049
Within Groups	134.256	22	6.103			
Total	**176.462**	**25**				
Single Factor ANOVA of Modified Hilsenhoff Index Scores						
Between Groups	2.824	3	0.941	**3.295***	0.039	3.049
Within Groups	6.283	22	0.286			
Total	**9.107**	**25**				
Single Factor ANOVA of Percent Dominant Taxa Index Scores						
Between Groups	60.487	3	20.162	0.291	0.831	3.049
Within Groups	1,523.667	22	69.258			
Total	**1,584.154**	**25**				
Single Factor ANOVA of Modified Percent Mayfliy Index Scores						
Between Groups	683.751	3	227.917	1.863	0.165	3.049
Within Groups	2,692.133	22	122.370			
Total	**3,375.885**	**25**				

* Significant at $p<0.05$

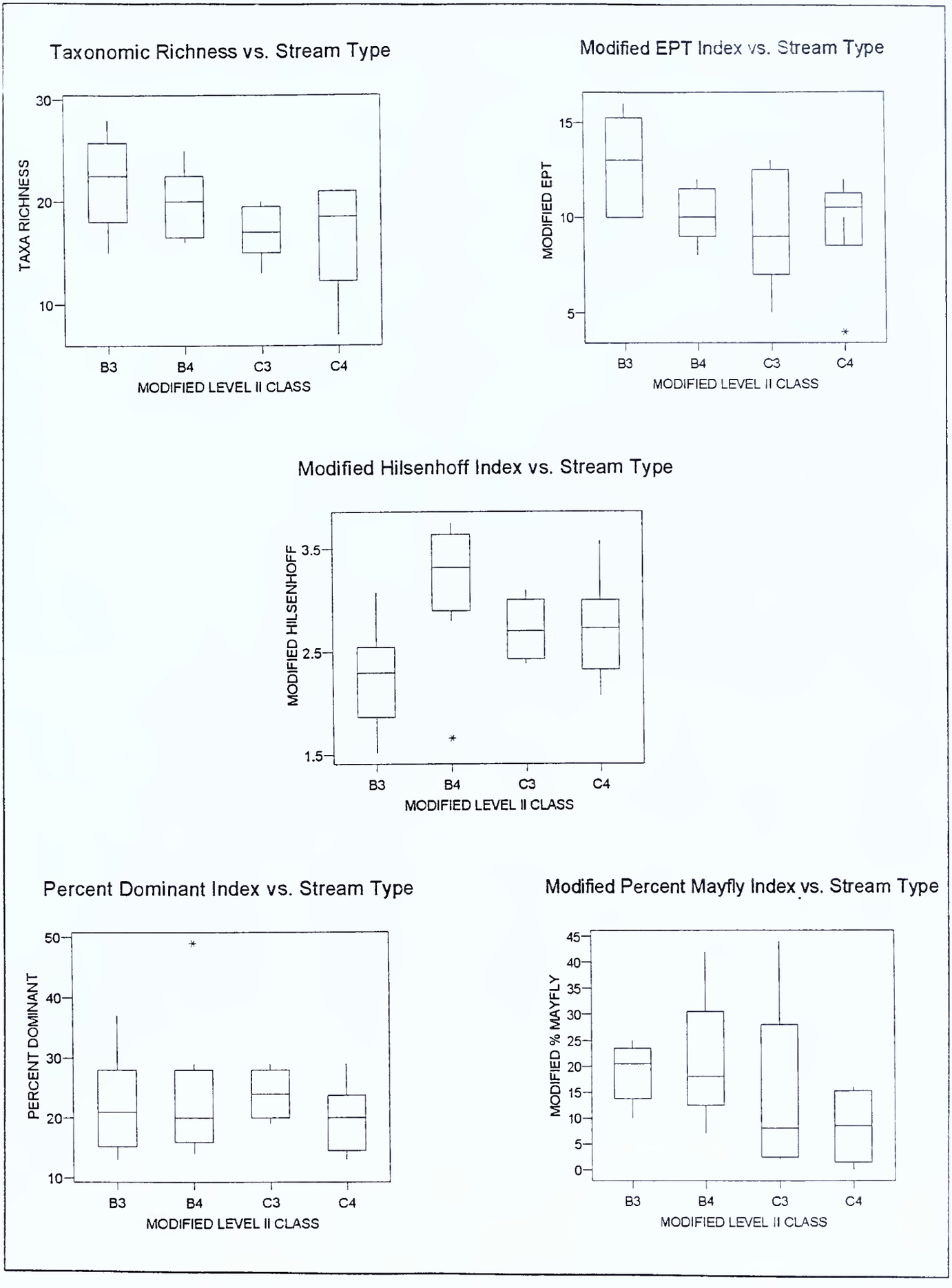

Figure 11. Summary of Data Set 3 Metric Scores Based on Modified Level II Stream Type Designation

Relationships Between Stream Reach Channel Morphology and Metric Scores

Channel substrate particle size, entrenchment, and slope are the stream reach morphology variables that have the greatest influence on the metric scores of the 26 HQ-CWFs included in data set 3 (non-outlier, type B and C streams). Taxa richness, modified EPT, and modified Hilsenhoff index scores are significantly correlated to substrate particle size, as described by d_{15}, d_{35}, and d_{50} values. Modified EPT and modified Hilsenhoff index scores also are significantly related to the amount of very coarse (percent boulder) materials present in the stream channel. In addition, modified Hilsenhoff index scores are influenced by amount of silt and clay (percent silt/clay) in the stream channel. Channel morphology parameters that are significantly correlated with the metric scores of data set 3 sample sites are summarized in Table 12.

In addition to channel substrate composition, surface water slope and channel entrenchment substantially influence the metric scores of sample sites. A statistically significant correlation exists between surface water slope and modified Hilsenhoff index scores. Entrenchment ratio, which is the primary stream reach morphology variable that distinguishes Rosgen level I type B streams from type C streams, is significantly correlated to taxa richness and modified EPT index scores.

Although the mean Hilsenhoff index scores of level I type B and C streams are not significantly different, the mean Hilsenhoff index scores of the modified level II stream types differ significantly. Modified level II data indicate that stream reaches characterized by low surface water slope values, in conjunction with small channel substrate materials, tend to have relatively high modified Hilsenhoff index scores. This relationship is particularly evident in modified level II B4 streams (Figure 12). ANOVA and Tukey multiple comparison tests indicate that Hilsenhoff index scores, d35 particle size, and surface water slope are significantly different between B3 and B4 stream types, and the d35 particle size of B4 and C4 streams are different than those of B3 and C3 streams.

*Table 12. **Summary of Correlation Analysis of Stream Reach Morphology Parameters and Metric Scores of Data Set 3 Sample Sites** (Table includes morphology parameters that are significantly correlated ($p < 0.05$) to at least one of the five metrics.)*

	Tax Rich	Mod EPT	Mod Hils	% Dom	Mod % May
Entrenchment	**-0.429***	**-0.410***	0.055	0.026	-0.326
Slope	-0.184	0.089	**-0.413***	-0.085	-0.101
d15	**0.437***	**0.579***	**-0.490***	-0.142	0.182
d35	0.376	**0.486***	**-0.518***	0.040	0.093
d50	**0.400***	**0.531***	**-0.473***	-0.074	0.139
Percent Silt/Clay	0.001	-0.320	**0.428***	-0.059	0.083
Percent Boulder	0.231	**0.398***	**-0.412***	-0.076	0.137

* $p < 0.05$

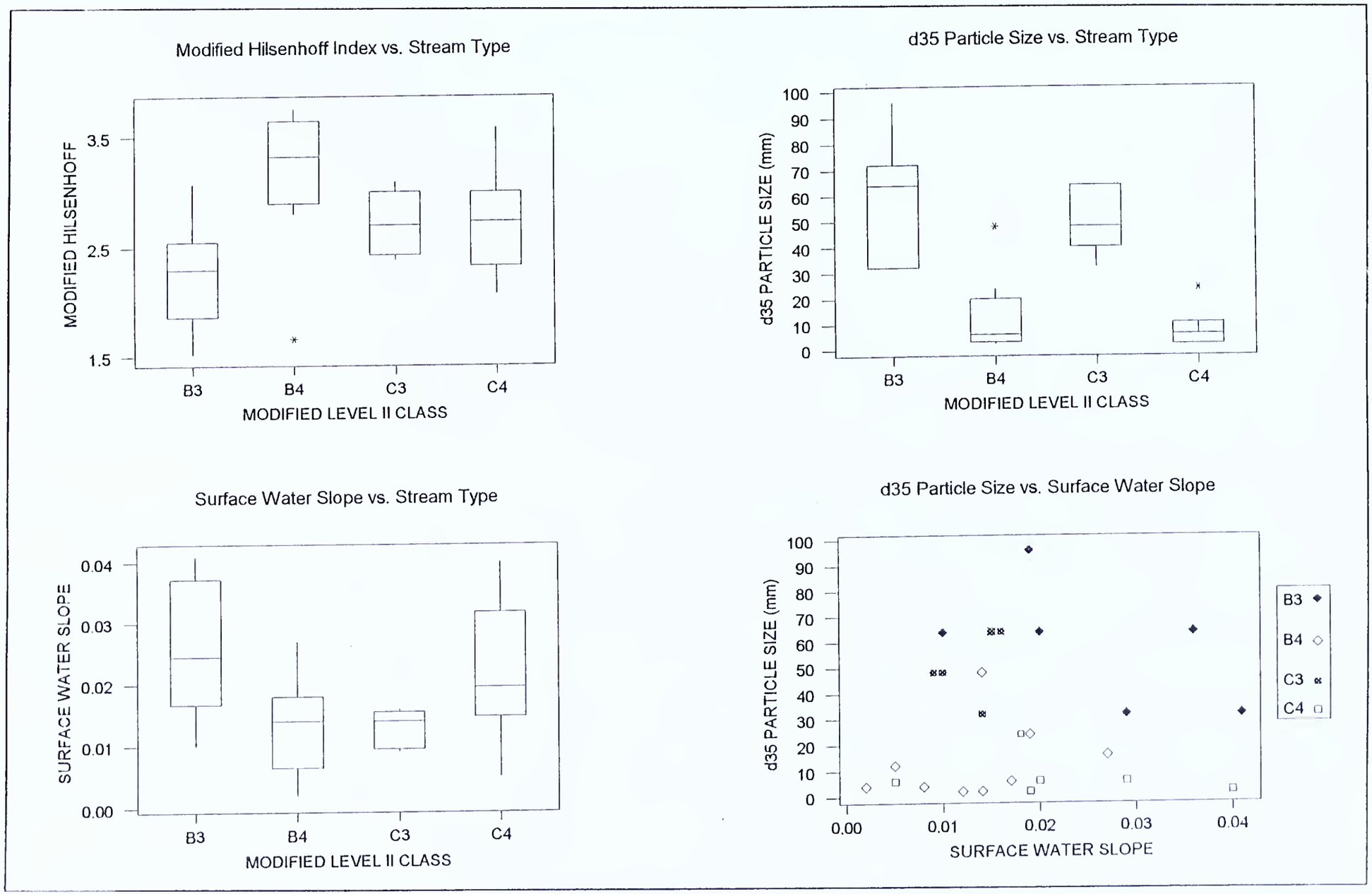

Figure 12. Box-and-Whisker and Scatter Plots Showing Relationship Among Modified Hilsenhoff Index Scores, d35 Particle Size, Surface Water Slope, and Modified Level II Stream Type Designation

DISCUSSION

Three of the five stream reach morphology parameters used in the Rosgen classification system are significantly correlated with at least one of the metrics included in this study. As d50 particle size increases, taxonomic richness and modified EPT index scores increase, and modified Hilsenhoff index scores decrease. As entrenchment ratios increase, taxonomic richness and modified EPT index scores decrease. Low surface water slope values correspond to elevated modified Hilsenhoff index scores, especially in streams where low surface water slope values coincide with channel substrates that are characterized by low d_{35} particle size.

In contrast to the Rosgen stream reach classification parameters, stream order designation is not significantly correlated with any of the five metrics included in this study. Furthermore, there are no significant differences between the mean metric scores of sample sites when they are grouped based on stream order designation. However, significant differences exist among the mean scores of several of the metrics when sample sites are grouped based on Rosgen stream type designation. Thus, the results of this study indicate Rosgen stream classification designation is more effective at partitioning biological variation among HQ-CWFs than stream order.

Entrenchment, channel substrate composition, and slope are the stream reach morphology variables that have the greatest influence on the macroinvertebrate communities included in this study. Entrenchment ratio is a critical component of the Rosgen stream classification system and is largely responsible for the system's effectiveness at partitioning biological variation among HQ-CWFs. Entrenchment ratio describes the vertical containment of the stream channel and provides insight into how stream energy is dissipated during high flows. For example, the top-of-bank elevations of entrenched streams (stream types F and G) are much higher than bankfull stage (Figure 13). At flows greater than bankfull stage, streamflow is contained within the streambanks and stream depth increases much faster than width. During floods, this containment of streamflow, which results in stream energy being exerted on both streambanks, is partly responsible for the high bank erosion rates observed in entrenched streams (Rosgen, 1996). In contrast to entrenched streams, slightly entrenched streams (stream types C and E) overtop their streambanks at flows greater than bankfull stage, and stream width increases substantially and stream energy is dissipated as streamflow moves onto the stream's relatively broad floodplain. The vertical containment of moderately entrenched streams (type B streams) is intermediate to that of entrenched and slightly entrenched streams.

Entrenchment ratio, which is the primary stream reach morphology variable that distinguishes Rosgen level I type B streams from type C streams, is significantly correlated to taxonomic richness and modified EPT index scores, and taxonomic richness is significantly different between level I type B and C streams. Although there is no statistically significant difference between the mean modified EPT index scores of level I or modified level II stream types, modified level II B3 streams tend to have higher modified EPT index scores than the other stream types (Figure 11). Furthermore, the influence of entrenchment on EPT communities is reflected in the significantly different modified percent mayfly metric scores of B and C streams (Figure 9). The most noticeable difference in the mayfly communities of B vs. C streams is the occurrence of the pollution intolerant genus *Paraleptophlebia* (Ephemeroptera: Leptophlebiidae). This genus is common in B streams (present at 87 percent of the B streams), but is relatively rare in type C streams (present at 23 percent of the C streams).

The Rosgen classification system is based on a suite of parameters that describe stream reach channel morphology and floodplain characteristics. For each of these parameters, a range of values (category intervals) were developed based on frequency histograms of data collected at stable, natural stream reaches (Rosgen, 1996). These category intervals, which are broad enough to account for the natural variability in morphological conditions associated with channel adjustment processes, are used in the Rosgen classification process to group streams into consistent, reproducible natural stream type

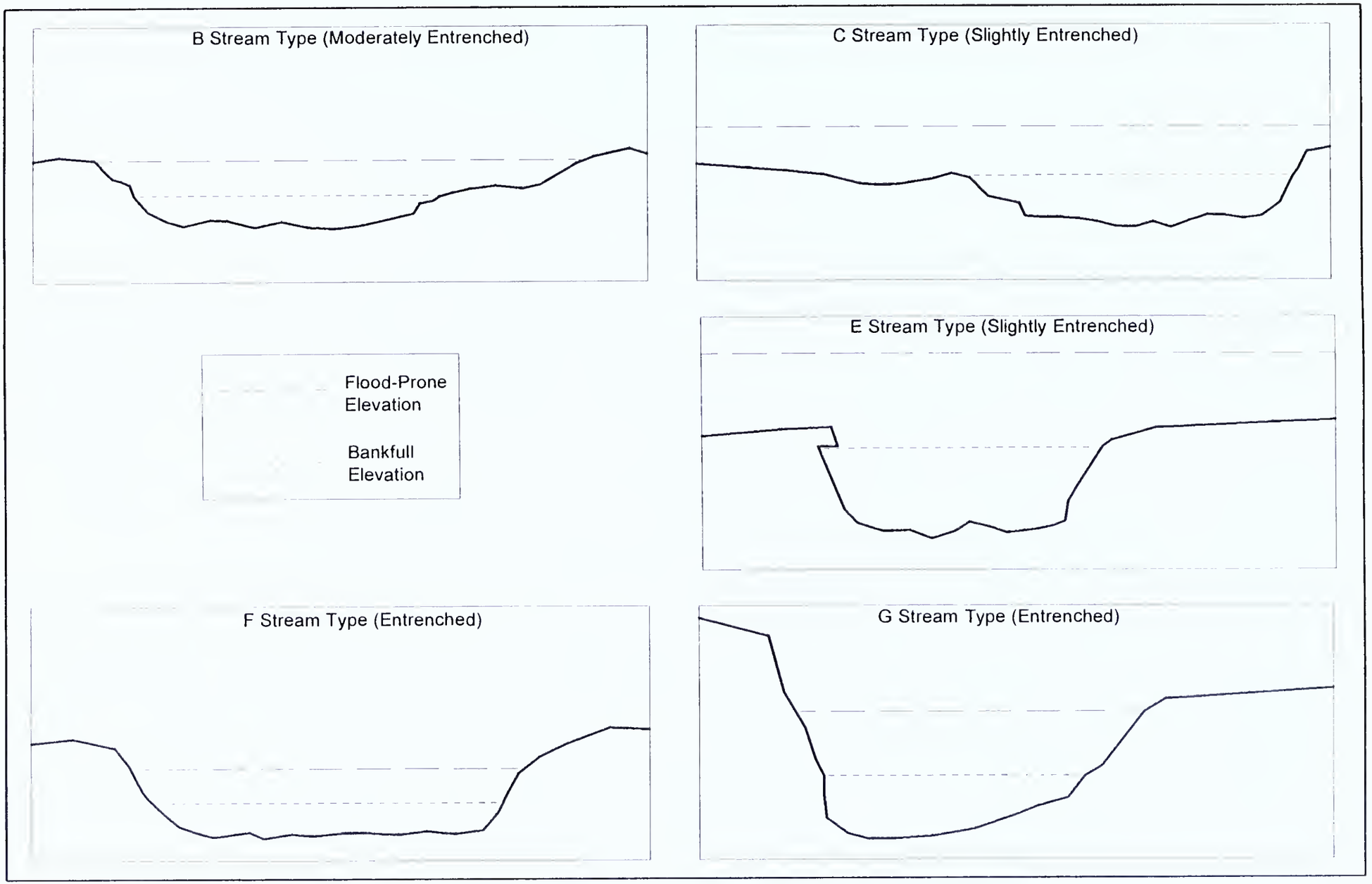

Figure 13. Examples of Entrenched, Moderately Entrenched, and Slightly Entrenched Stream Types

categories. Therefore, in addition to its utility as a method of identifying similar stream reaches, Rosgen classification information is useful for identifying streams that have deviated from stable, natural morphological conditions.

The Rosgen classification data collected in this study indicate that the morphological conditions of several sample sites are in disequilibrium and have deviated from stable, natural conditions. These sites include Letort Spring Run (LTRT), both sites on Hammer Creek (HAMU and HAML), Horse Hollow Run (HORS), and Unnamed Tributary to East Branch Codorus Creek (UEBC). For example, LTRT and HAMU do not fit into any of the Rosgen classification categories, but these sites closely resemble G stream types, which Rosgen (1996) describes as occurring in valleys such as those of LTRT and HAMU under conditions of "instability or disequilibrium that are often imposed by watershed changes and/or direct channel impacts." Several miles downstream of HAMU, HAML also is in disequilibrium. Although HAML fits into the F4 category, it is located in a type of valley that is typically drained by type B streams rather than type F streams, indicating that this stream is not in equilibrium with its valley. F stream types occur naturally in canyons, gorges, fault-controlled valleys, glacial outwash, and "U" shaped glacial troughs.

With the exception of Willow Creek (WILL) and Hutton Run (HUTT), most of the outliers in the original data set of 35 sample sites show some degree of departure from stable, natural morphological conditions. Willow Creek, which was determined to be an outlier based solely on limestone-influenced water chemistry, is the only limestone influenced site with stable, natural morphological characteristics. In addition to stable morphological conditions, the macroinvertebrate community of Willow Creek is characterized by metric scores comparable to other type C streams, with the exception of a very high modified percent mayfly index score due to a high abundance of the genus *Isonychia* (Ephemeroptera: Isonychiidae). This relationship observed between stream reach morphological conditions and the biological integrity of the limestone influenced streams included in this study (WILL vs. LTRT, HAMU, and HAML) suggests that Rosgen classification data contains valuable information that could enhance evaluations of the ecological significance of streams and rivers.

The Rosgen level I delineations referred to in this study were determined based on field data gathered during level II assessments. However, level I classification is designed to be a coarse-scale geomorphic characterization that can be performed using information taken from topographic and landform maps and aerial photographs, followed by subsequent verification with field data from selected reference reaches. Thus, level I classifications performed in the office and verified in the field may provide water resource managers with an accurate, cost effective procedure for classifying streams and screening stream reach morphological conditions. Furthermore, the efficiency of Rosgen level I classification and data management could be greatly enhanced if these activities can be successfully conducted using GIS and spatial analysis software.

MANAGEMENT IMPLICATIONS

The data included in this study were useful for identifying several relationships between stream reach morphology and the macroinvertebrate communities of HQ-CWFs. Channel substrate characteristics, entrenchment, and surface water slope are the stream reach morphology features observed to have the greatest influence on the metric scores of these streams. Taxa richness, modified EPT, and modified Hilsenhoff index scores are influenced by channel substrate characteristics. Taxa richness and modified EPT index scores are influenced by entrenchment and modified Hilsenhoff index scores are influenced by surface water slope.

The Rosgen Stream Classification System provides a means for classifying and assessing streams based on stream reach morphology variables that substantially influence the physical characteristics and benthic macroinvertebrate communities of HQ-CWFs. Whereas no significant relationships exist between stream

order and metric scores, Rosgen classification designation is superior to stream order designation as a method for partitioning biological variability in HQ-CWFs and classifying these streams at the reach spatial scale.

The relationships observed between stream reach morphology and the biological integrity of the streams included in this study, limestone influenced streams in particular, indicate that Rosgen classification data contains valuable information pertaining to the general, morphological "state" or condition of stream reaches. This information provides objective, quantitative data for documenting the morphological conditions of streams with regard to deviations from stable, natural morphological conditions. The potential inclusion of this information in bioassessments and/or ecological significance evaluations deserves further investigation.

Other potential uses of Rosgen classification data include applications related to hydraulic geometry, flow resistance, grazing management techniques, fish habitat improvement structure suitability, stream channel restoration design, and watershed management activities based on stream type. Of particular interest, is the potential utility of Rosgen stream classification data to develop watershed management guidelines. Myers and Swanson (1992) identified how different Rosgen stream types responded to riparian grazing. Rosgen (1994) expanded on the findings of Meyers and Swanson and summarized the affects of grazing on different stream types with respect to their sensitivity to disturbance, recovery potential, sediment supply, streambank erosion potential, and the influence of vegetation at controlling stability.

In categorizing the riparian grazing data by stream type, Rosgen developed a framework for identifying stream reaches that are most sensitive to disturbance and have the highest recovery potential, based on stream type. It is highly probable that, if the relationships between additional watershed activities (e.g., land use/land cover changes, riparian vegetation conditions, the occurrence of specific farming practices) and Rosgen stream type designation were identified, stream classification could be used as a framework for organizing watershed data, developing watershed management guidelines, and effectively targeting a variety of watershed management and restoration activities.

Future investigation comparing the Rosgen classification data obtained in this study with classification data for the same stream reaches generated in the office would be valuable for determining whether office delineations, possibly using GIS software, are accurate for classifying stream reaches and describing stream reach morphology. If so, GIS-generated Rosgen classification information could provide water resource managers with a cost-effective procedure for classifying streams, screening stream reach morphological conditions, organizing watershed data, and targeting watershed management activities.

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Appendix A

Channel Cross-Section and Pebble Count Data

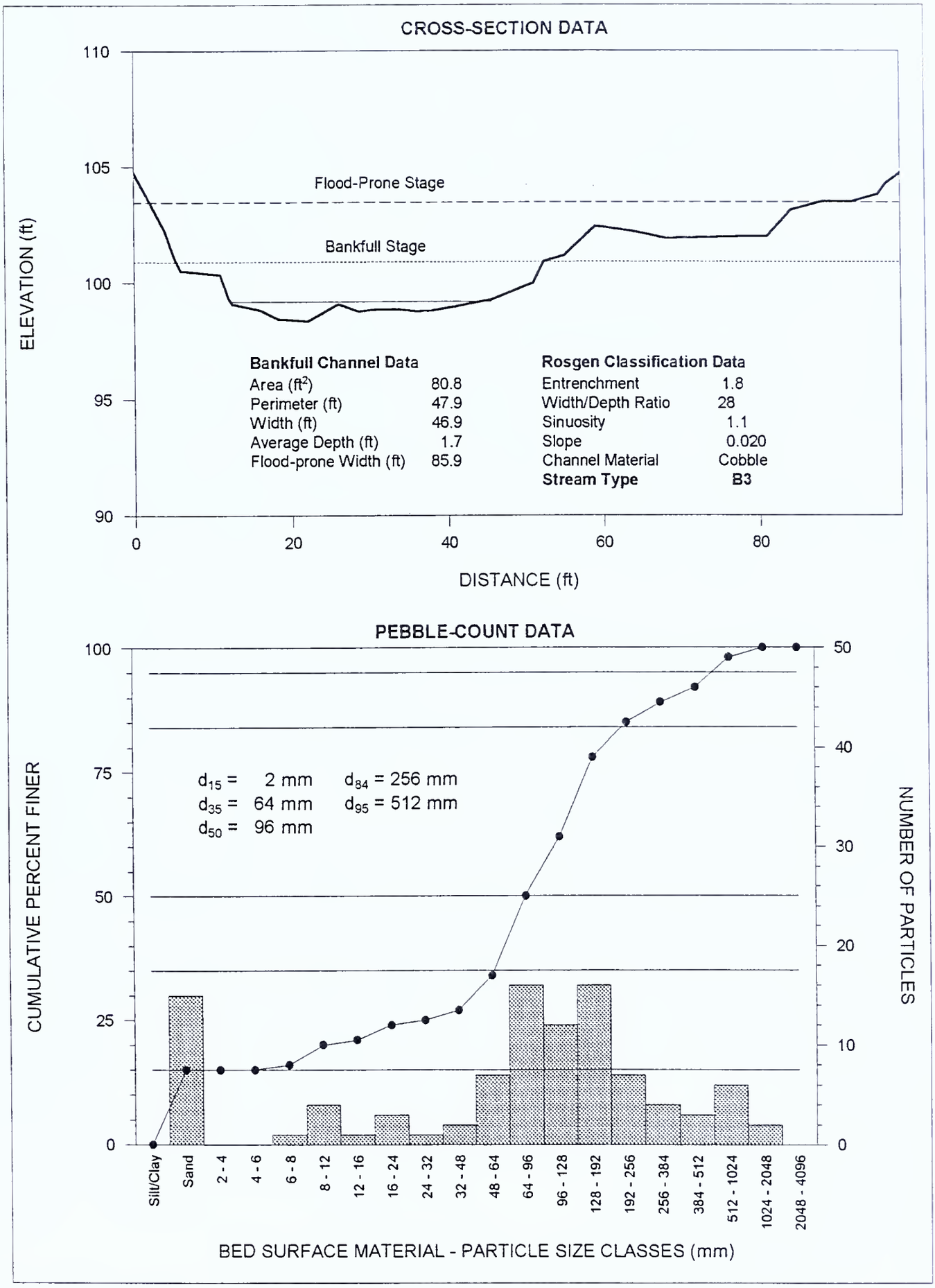


Figure A1. Cross-Section and Pebble Count Data From Asaph Run

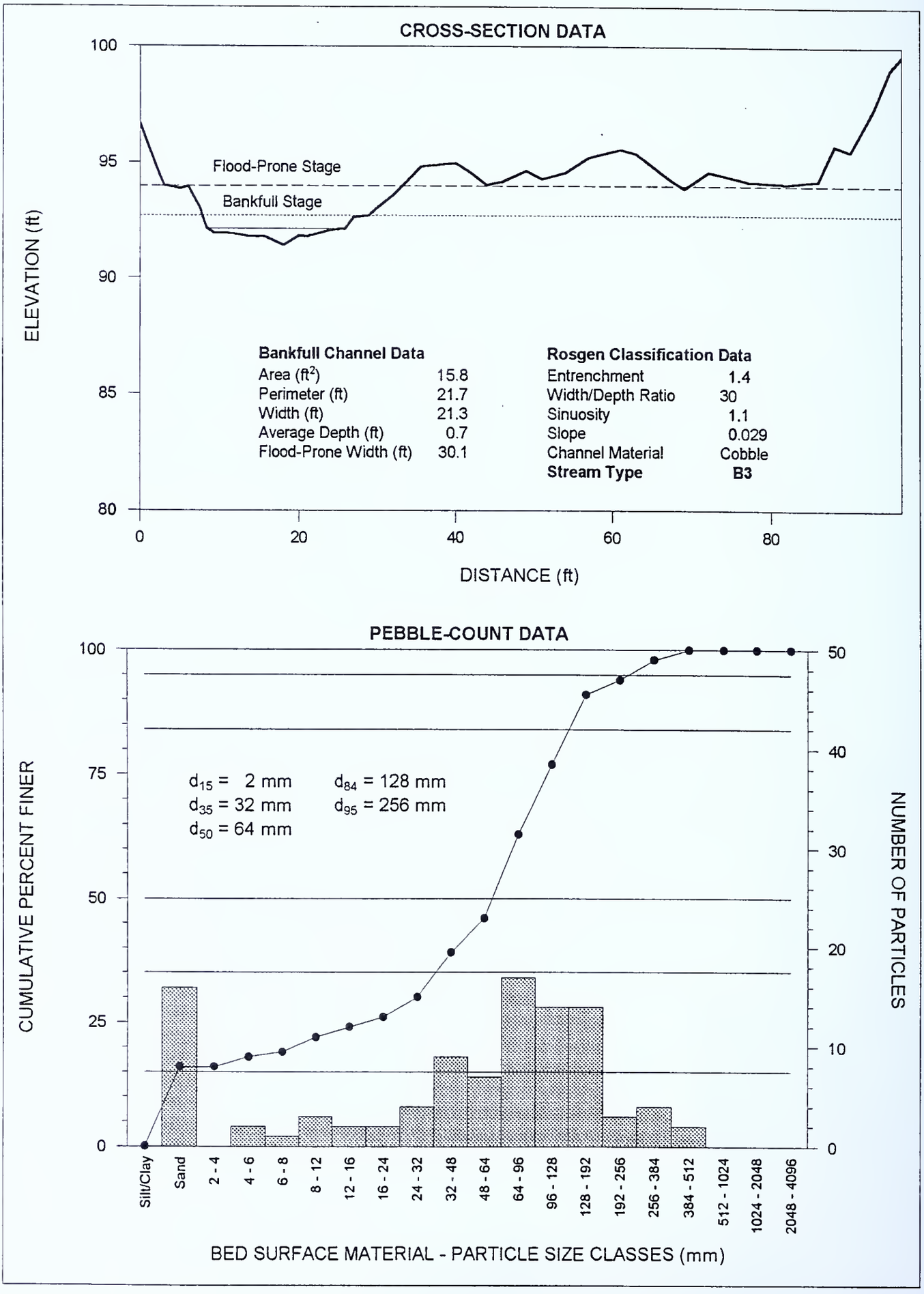


Figure A2. Cross-Section and Pebble Count Data From Baldwin Branch

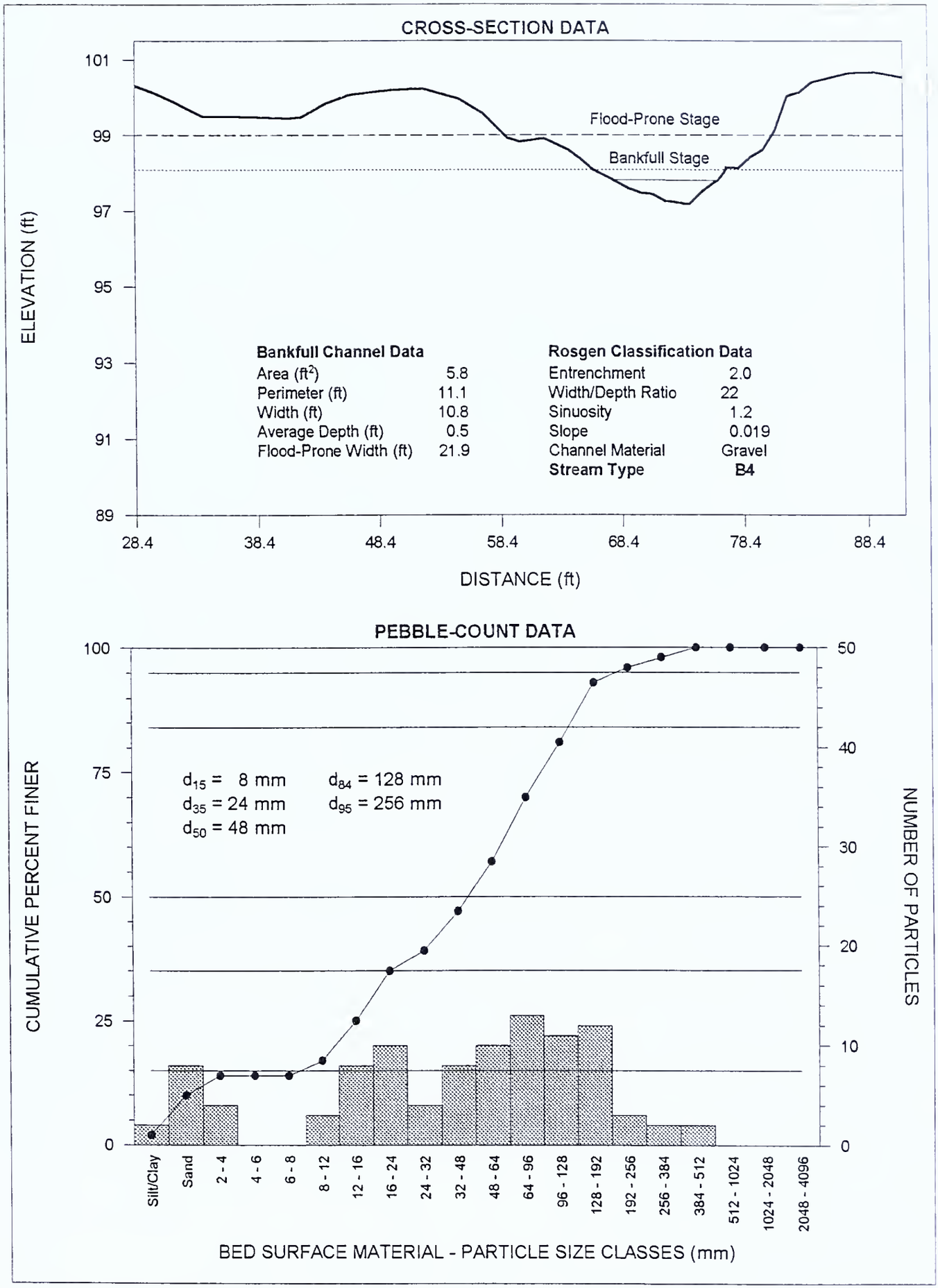


Figure A3. Cross-Section and Pebble Count Data From Cork Hill Creek

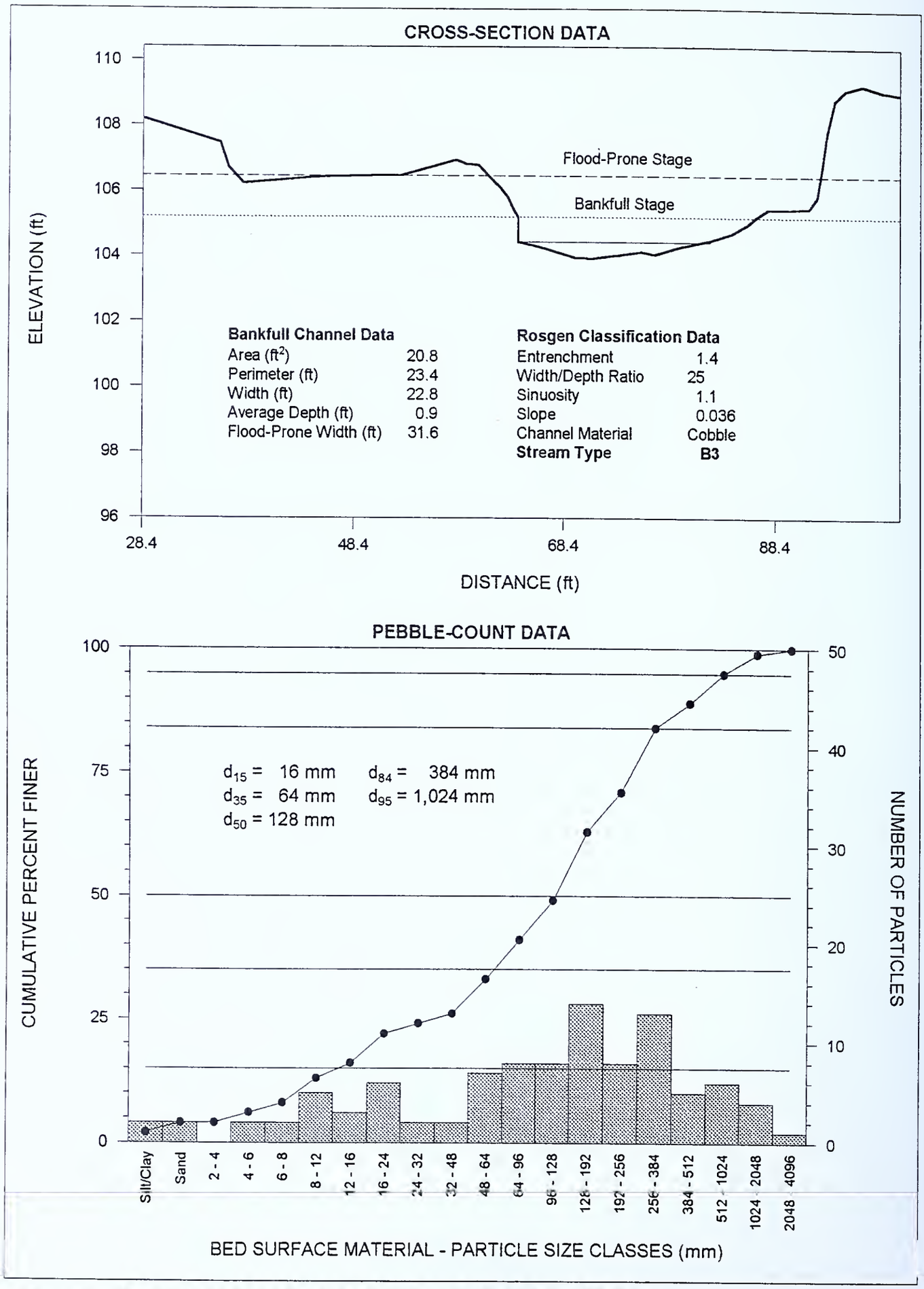


Figure A4. Cross-Section and Pebble Count Data From Deep Hollow

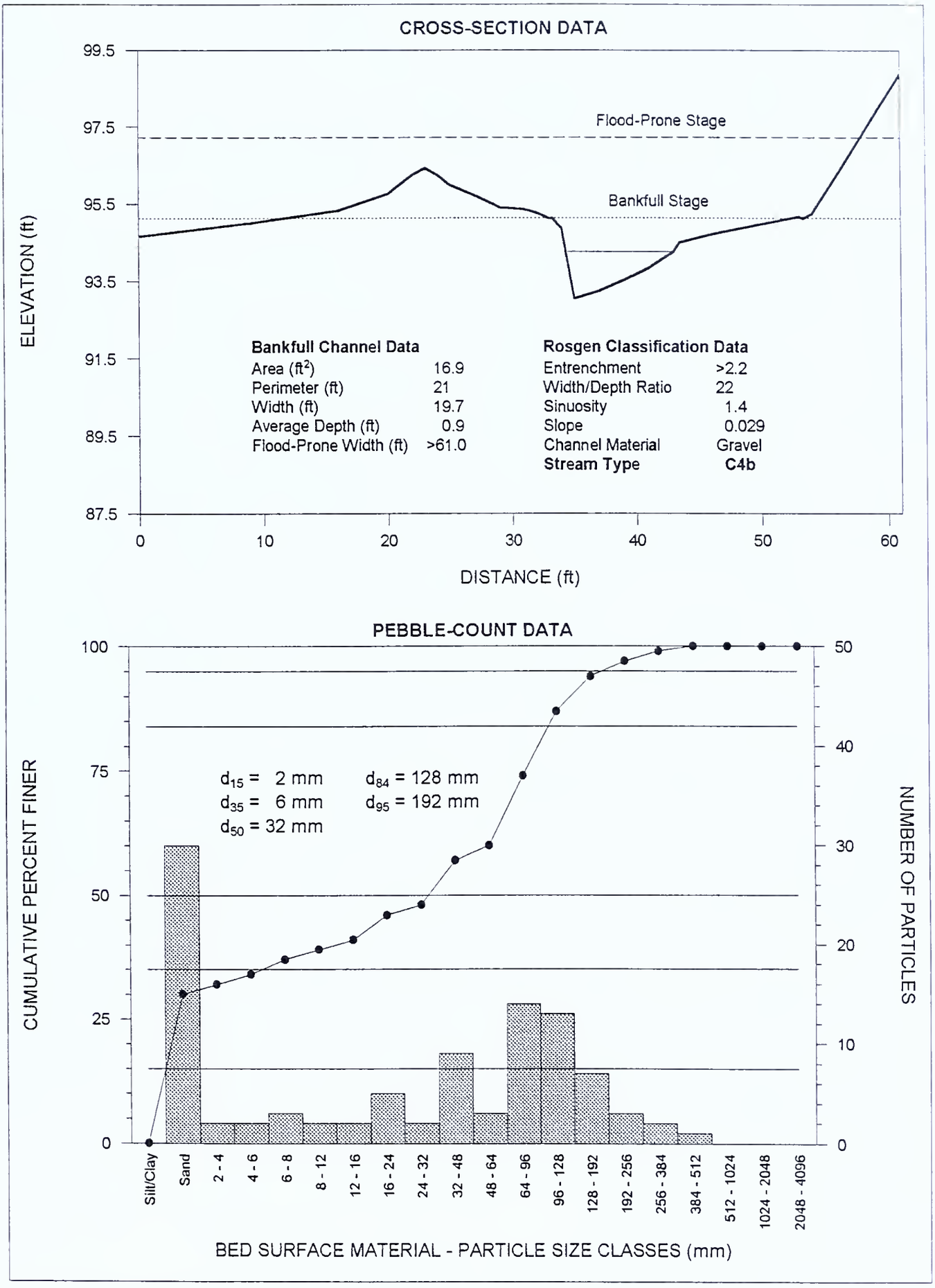


Figure A5. Cross-Section and Pebble Count Data From Dead Woman Hollow

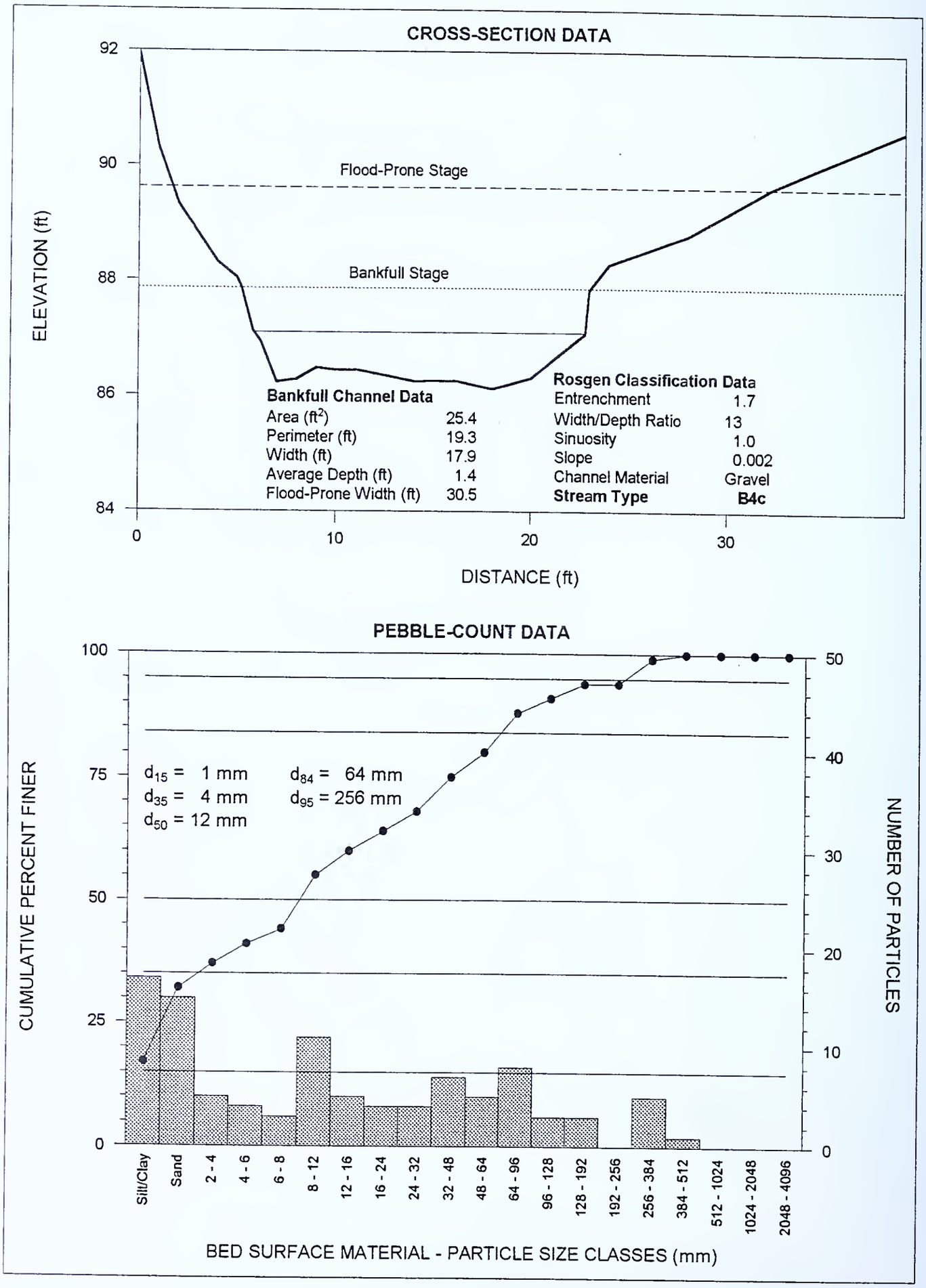


Figure A6. Cross-Section and Pebble Count Data From East Branch Codorus Creek

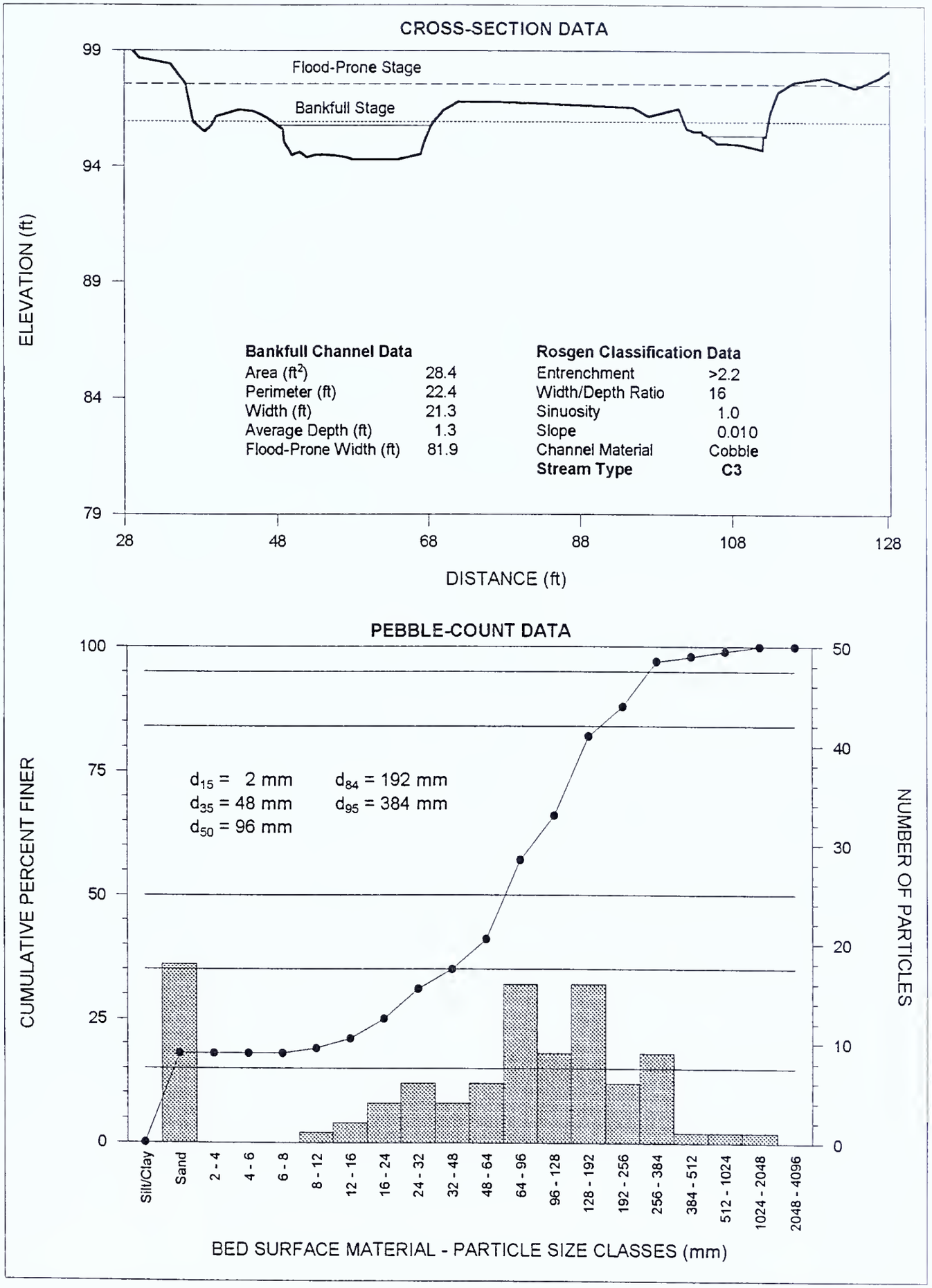


Figure A7. Cross-Section and Pebble Count Data From East Branch Lackawanna River

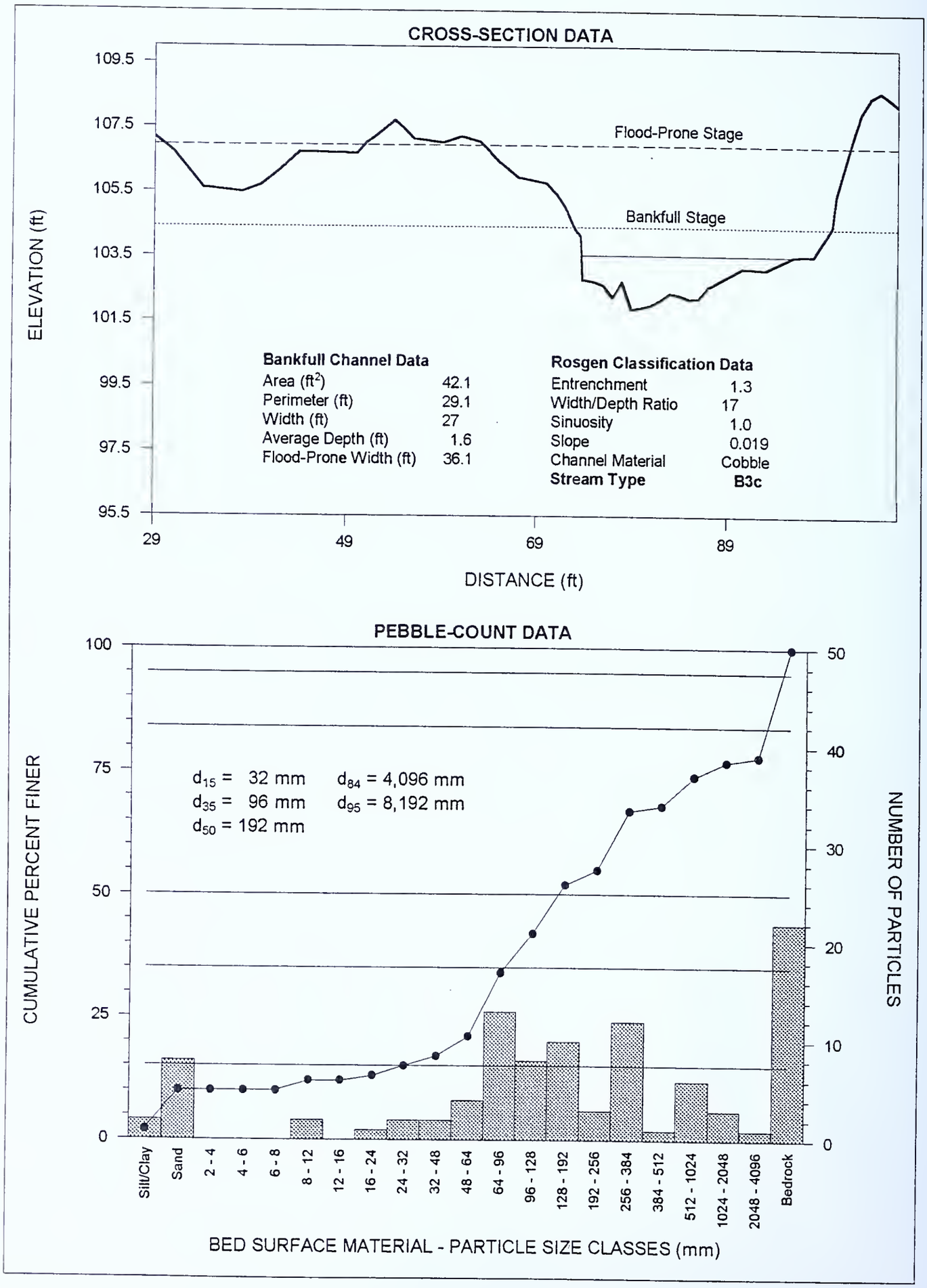


Figure A8. Cross-Section and Pebble Count Data From East Branch Roaring Brook

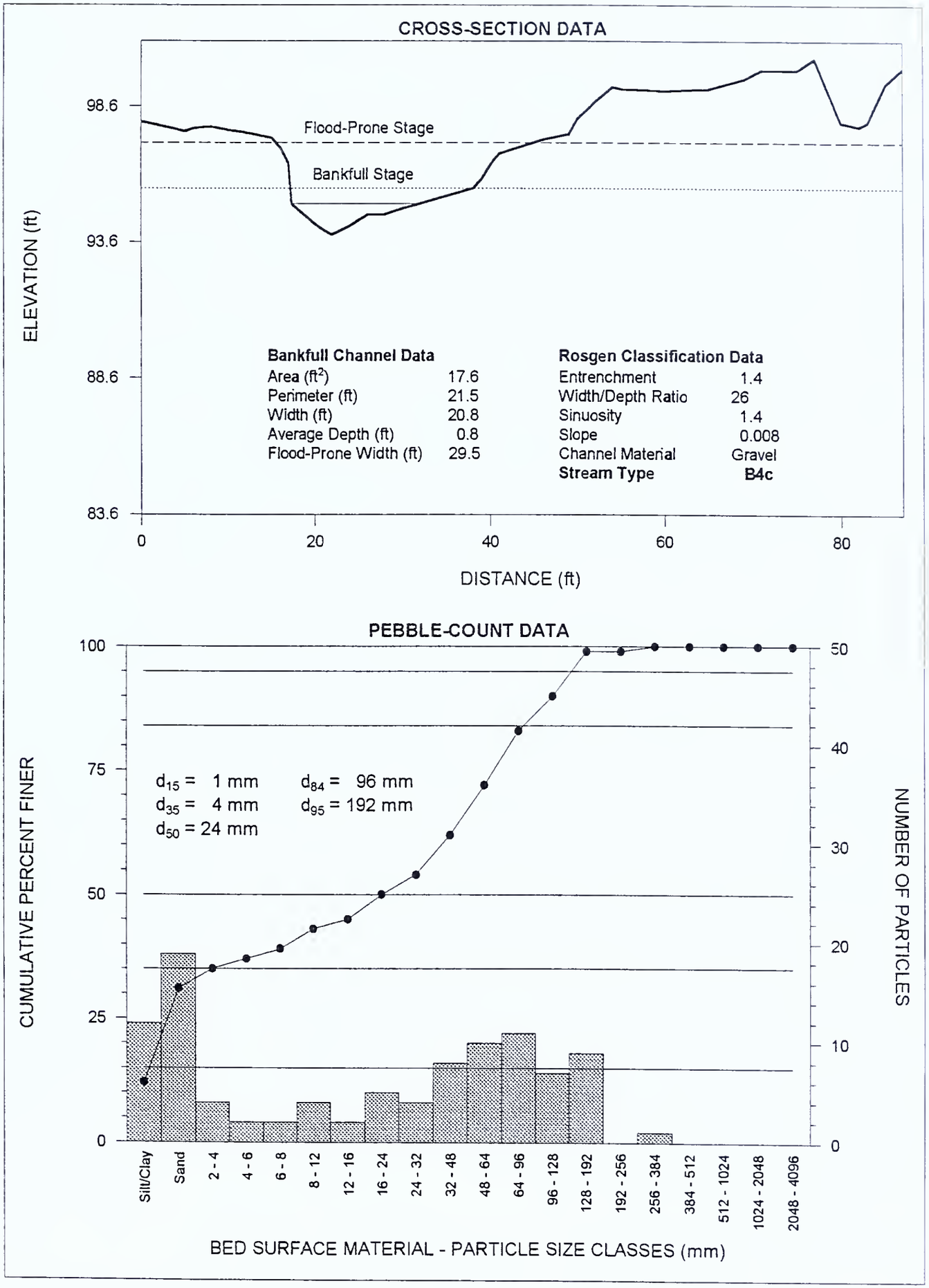


Figure A9. Cross-Section and Pebble Count Data From Gazzam Run

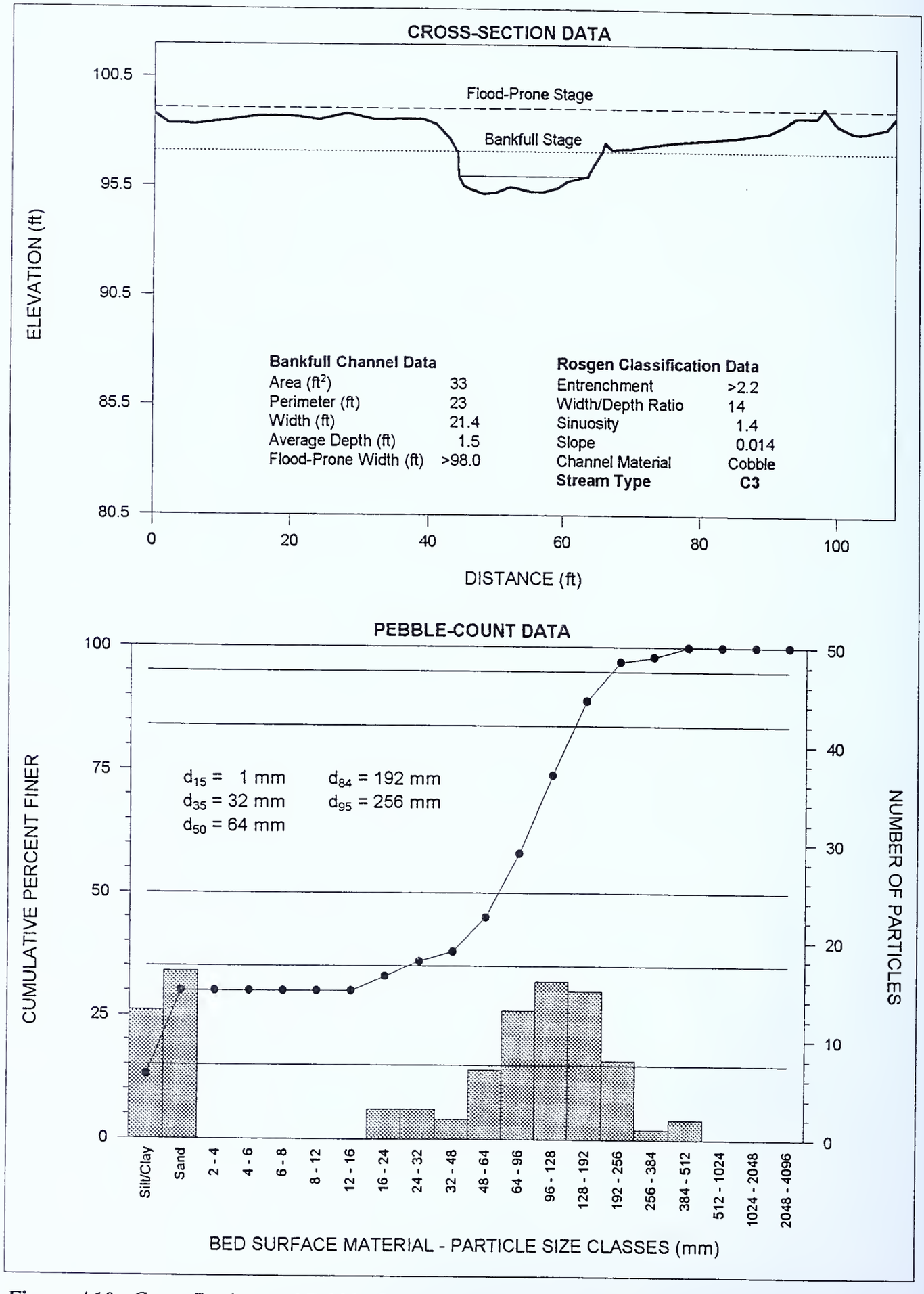


Figure A10. Cross-Section and Pebble Count Data From Greenlee Run

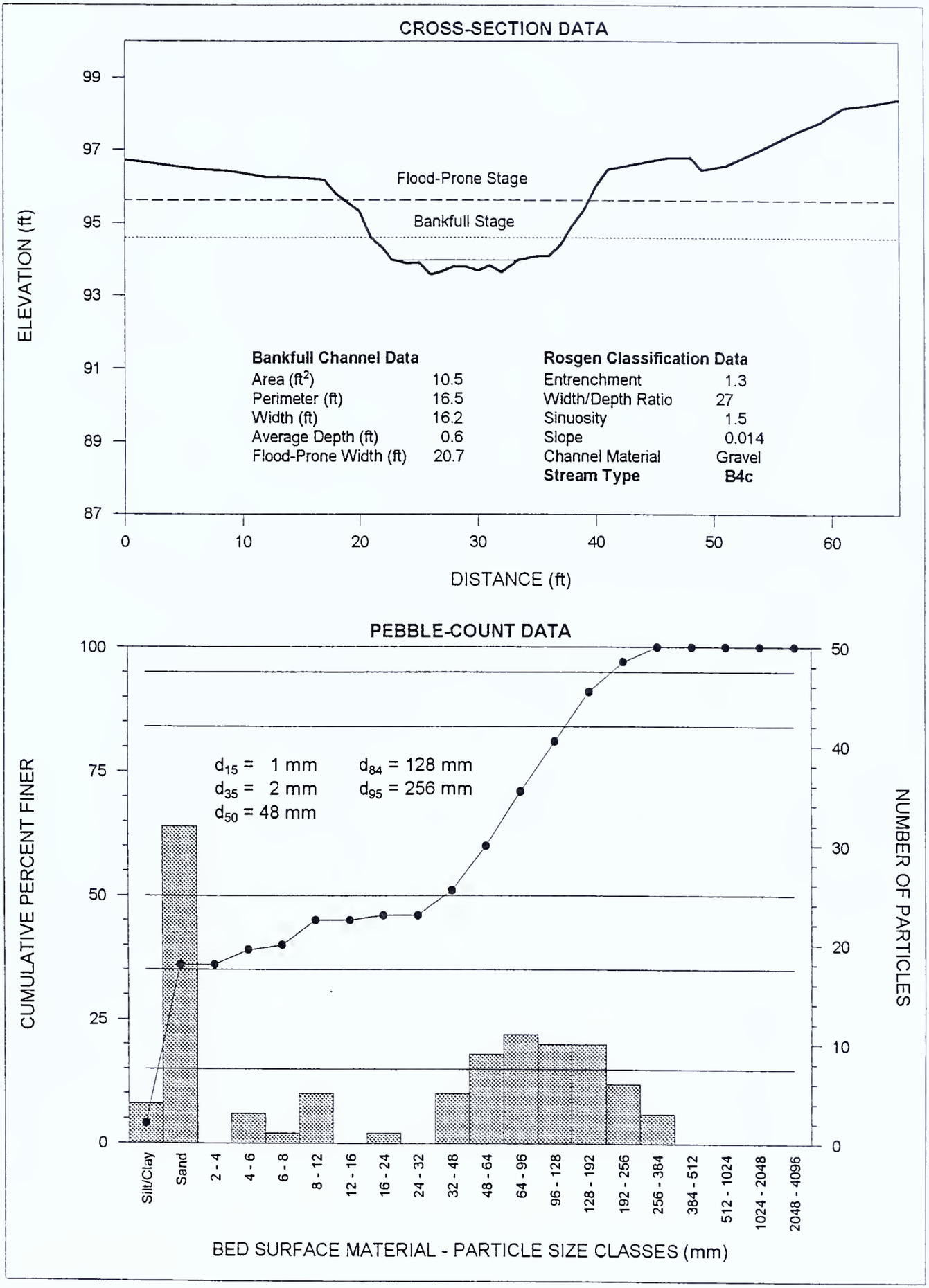


Figure A11. Cross-Section and Pebble Count Data From Green Run (Lower)

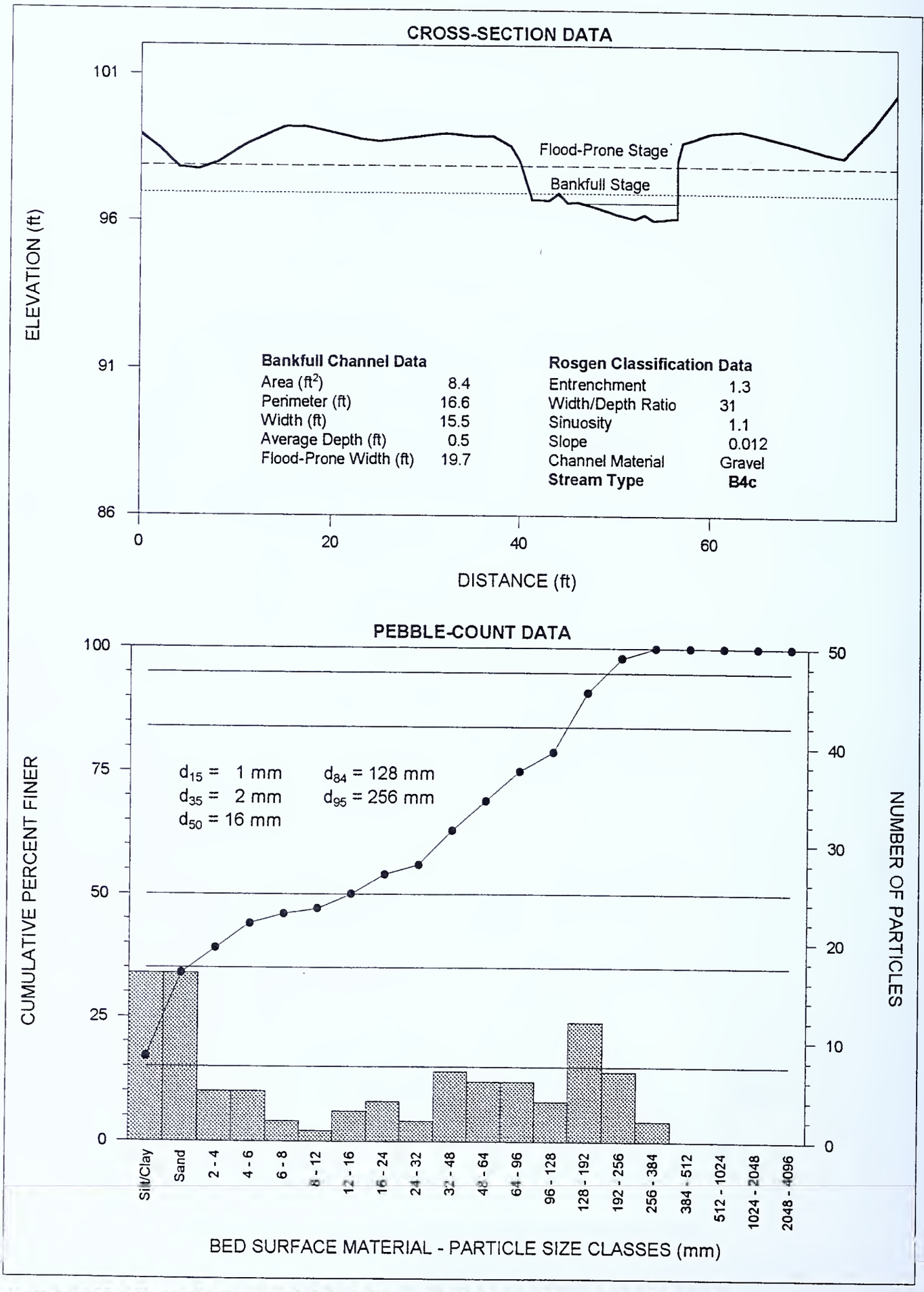


Figure A12. Cross-Section and Pebble Count Data From Green Run (Upper)

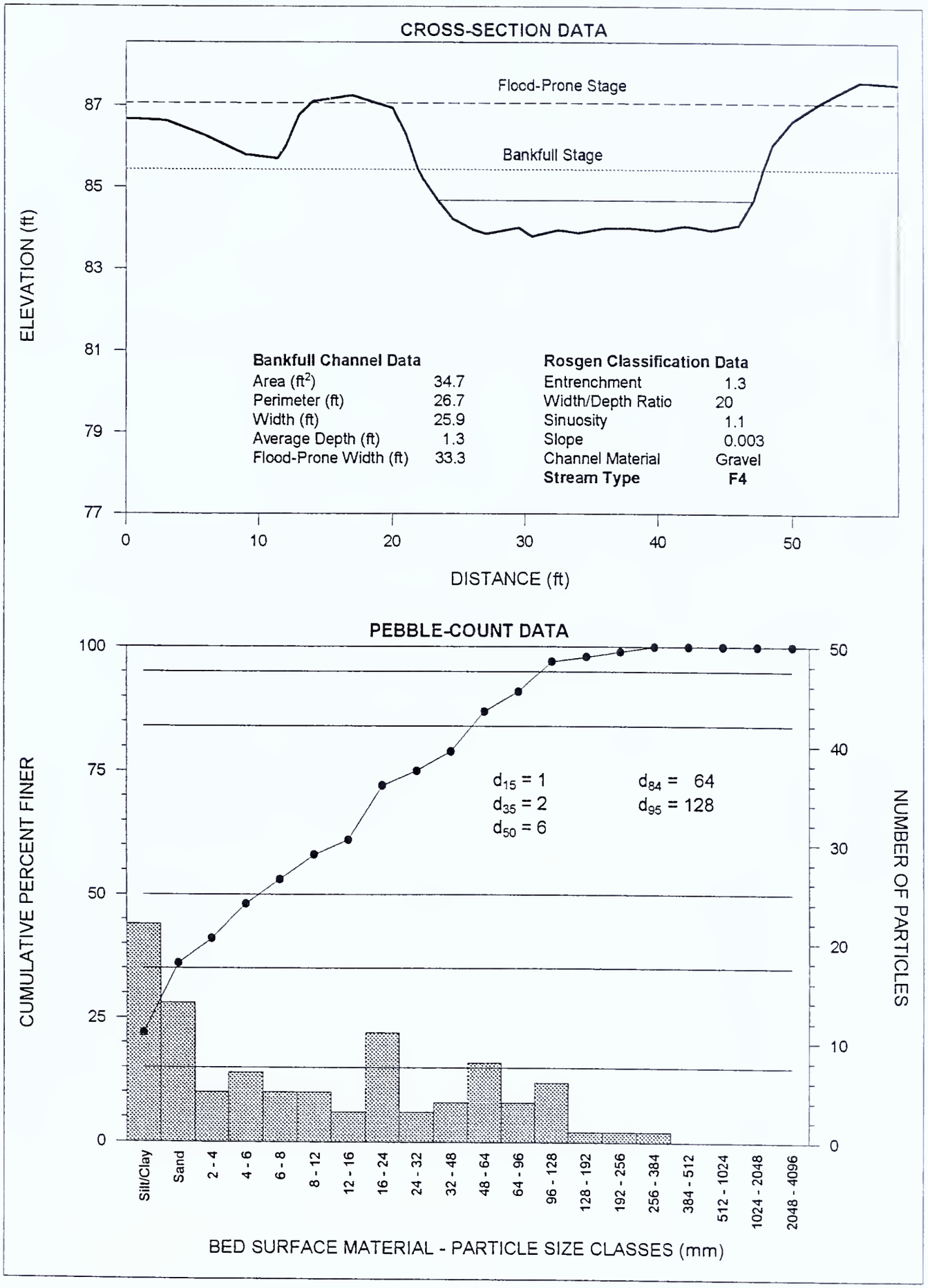


Figure A13. Cross-Section and Pebble Count Data From Hammer Creek (Lower)

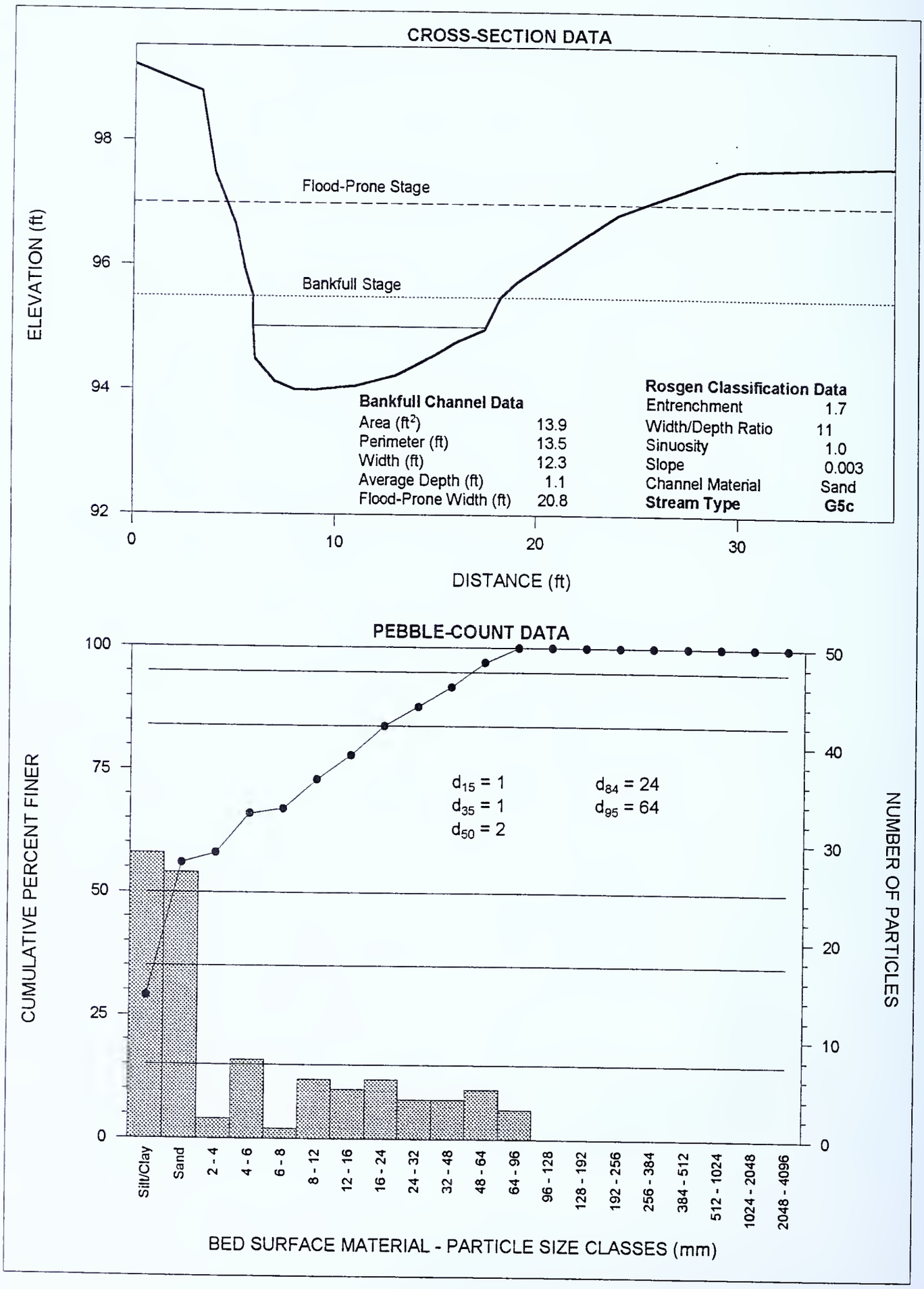


Figure A14. Cross-Section and Pebble Count Data From Hammer Creek (Upper)

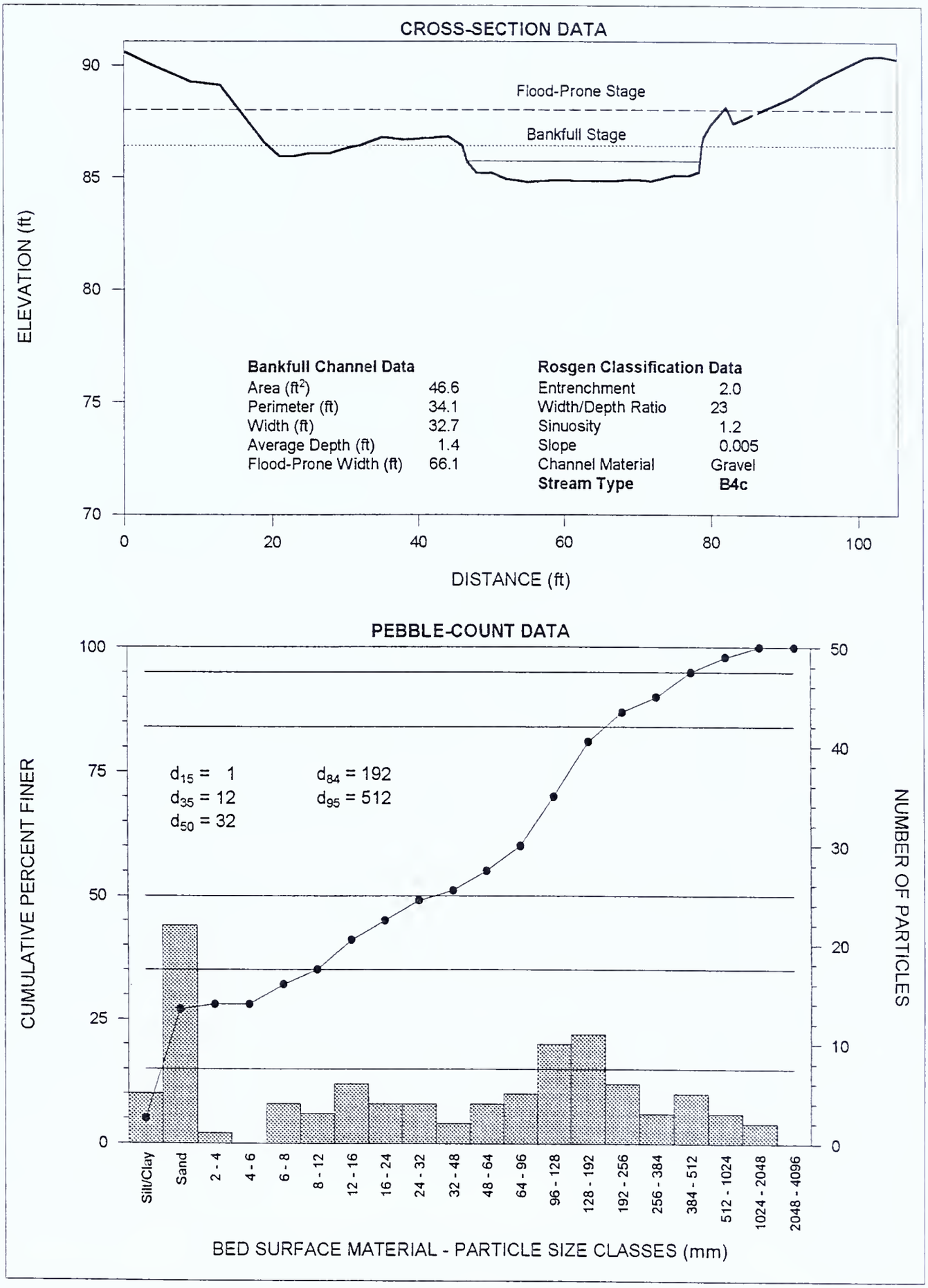


Figure A15. Cross-Section and Pebble Count Data From Harveys Creek

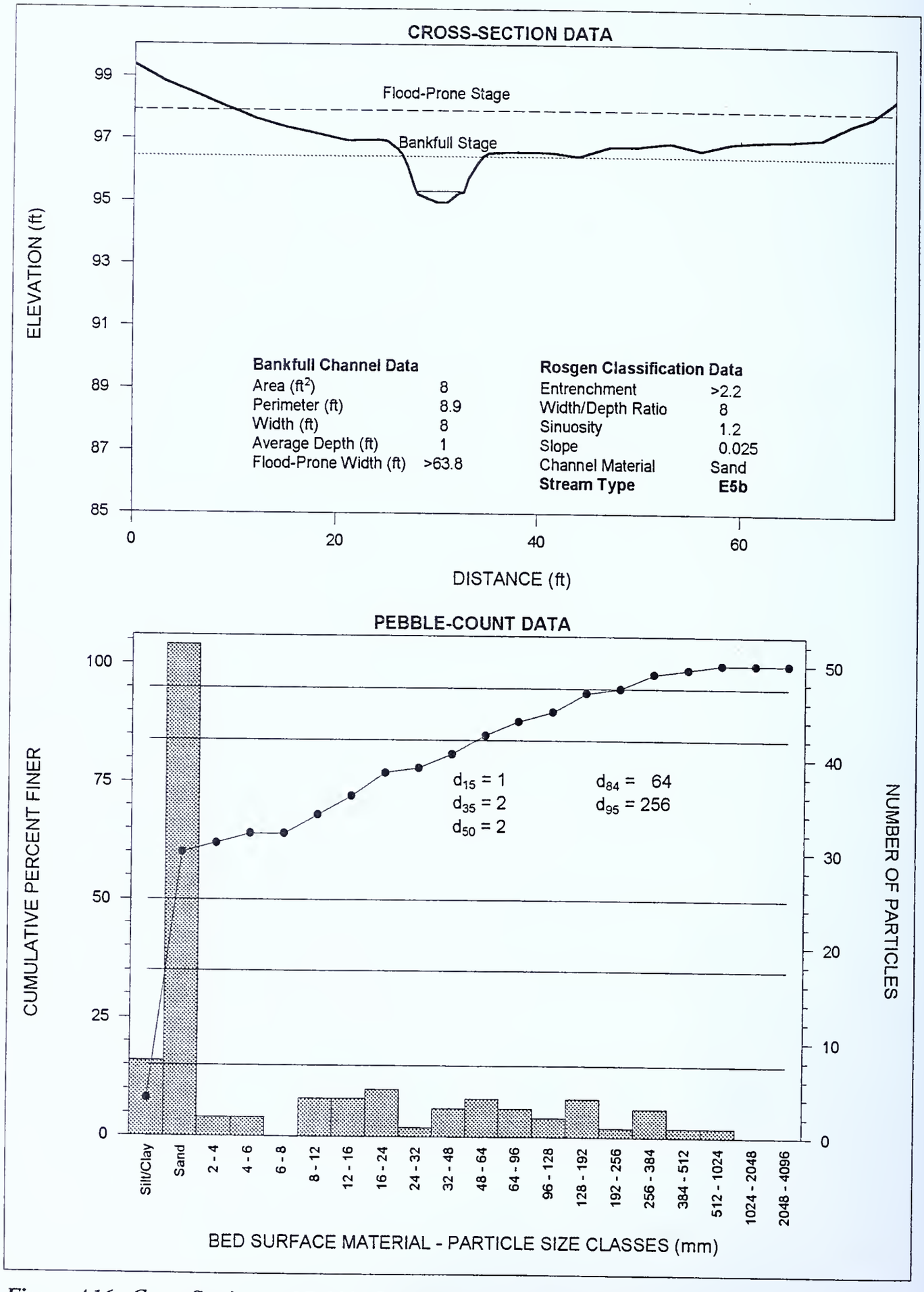


Figure A16. Cross-Section and Pebble Count Data From Horse Hollow

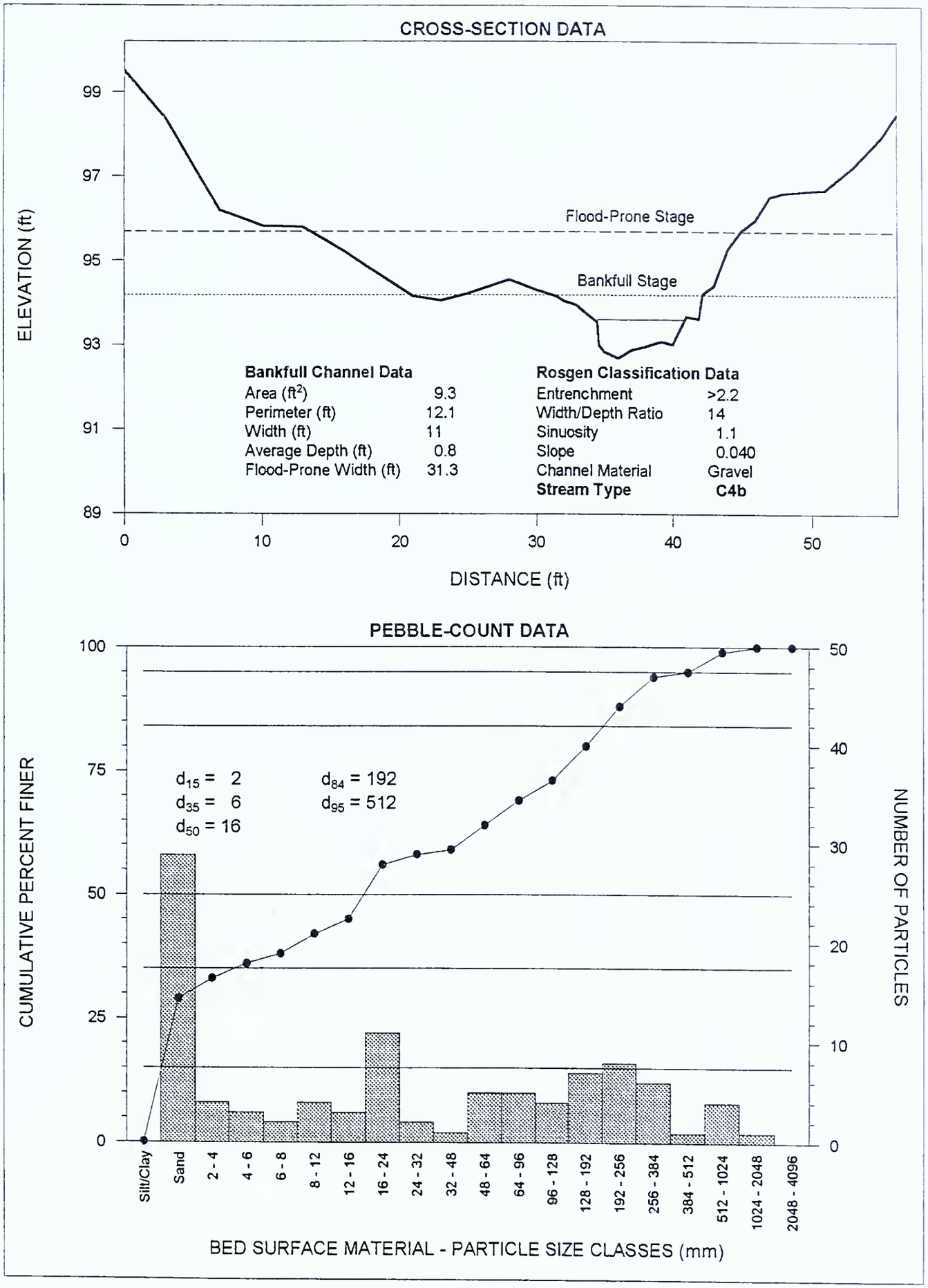


Figure A17. Cross-Section and Pebble Count Data From Hutton Run

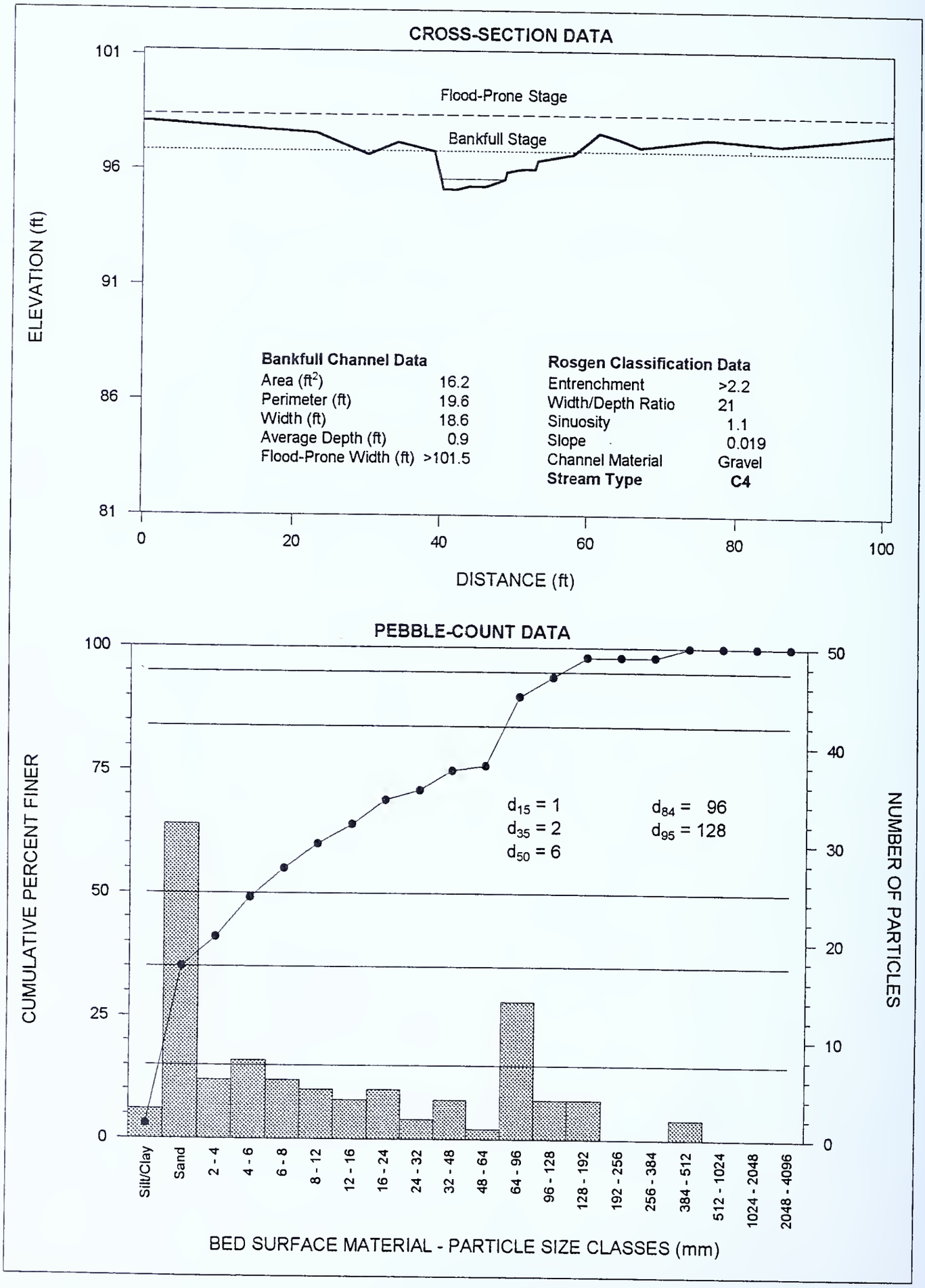


Figure A18. Cross-Section and Pebble Count Data From Iron Run

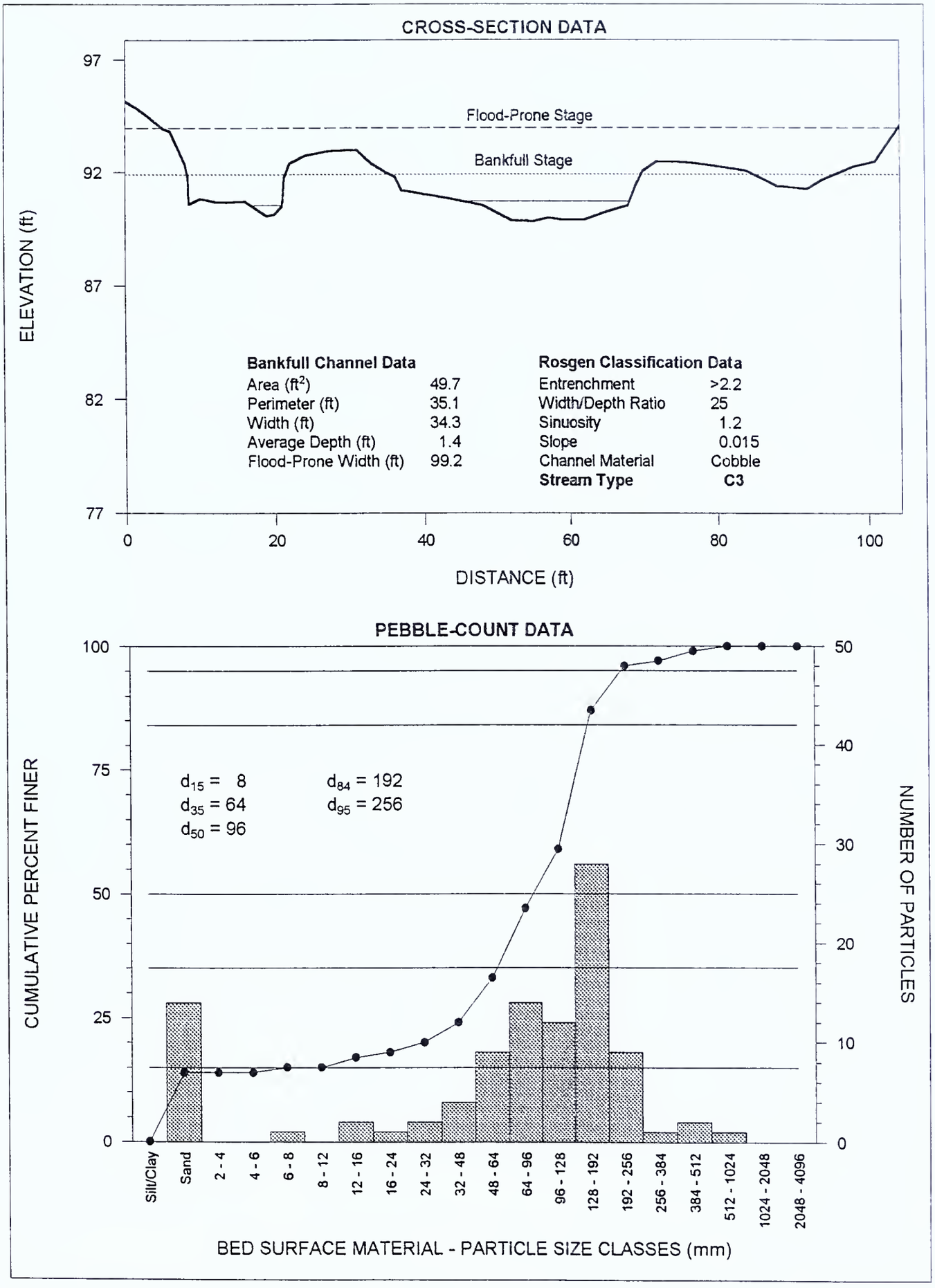


Figure A19. Cross-Section and Pebble Count Data From Lebo Run

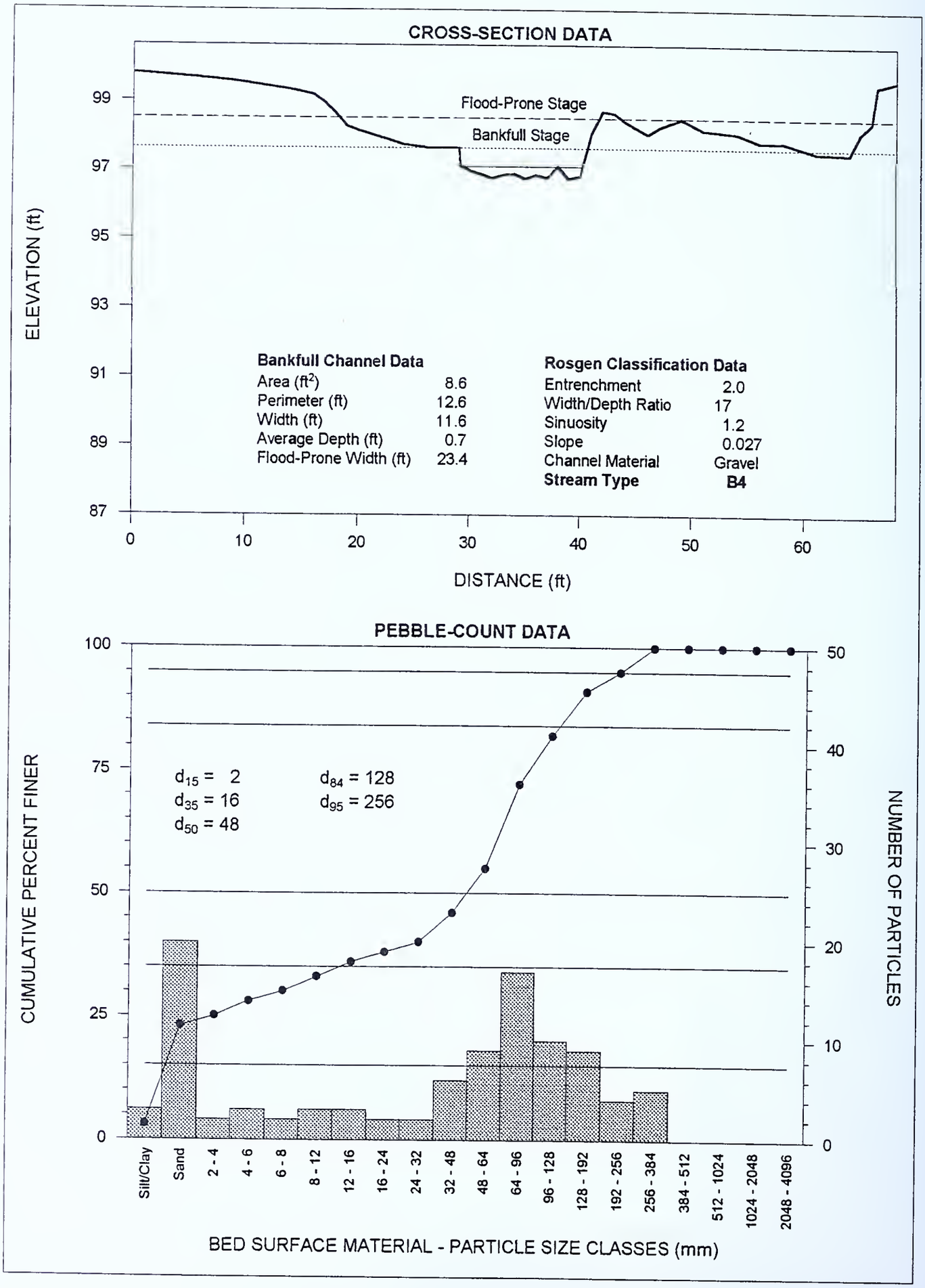


Figure A20. Cross-Section and Pebble Count Data From Little Moores Run

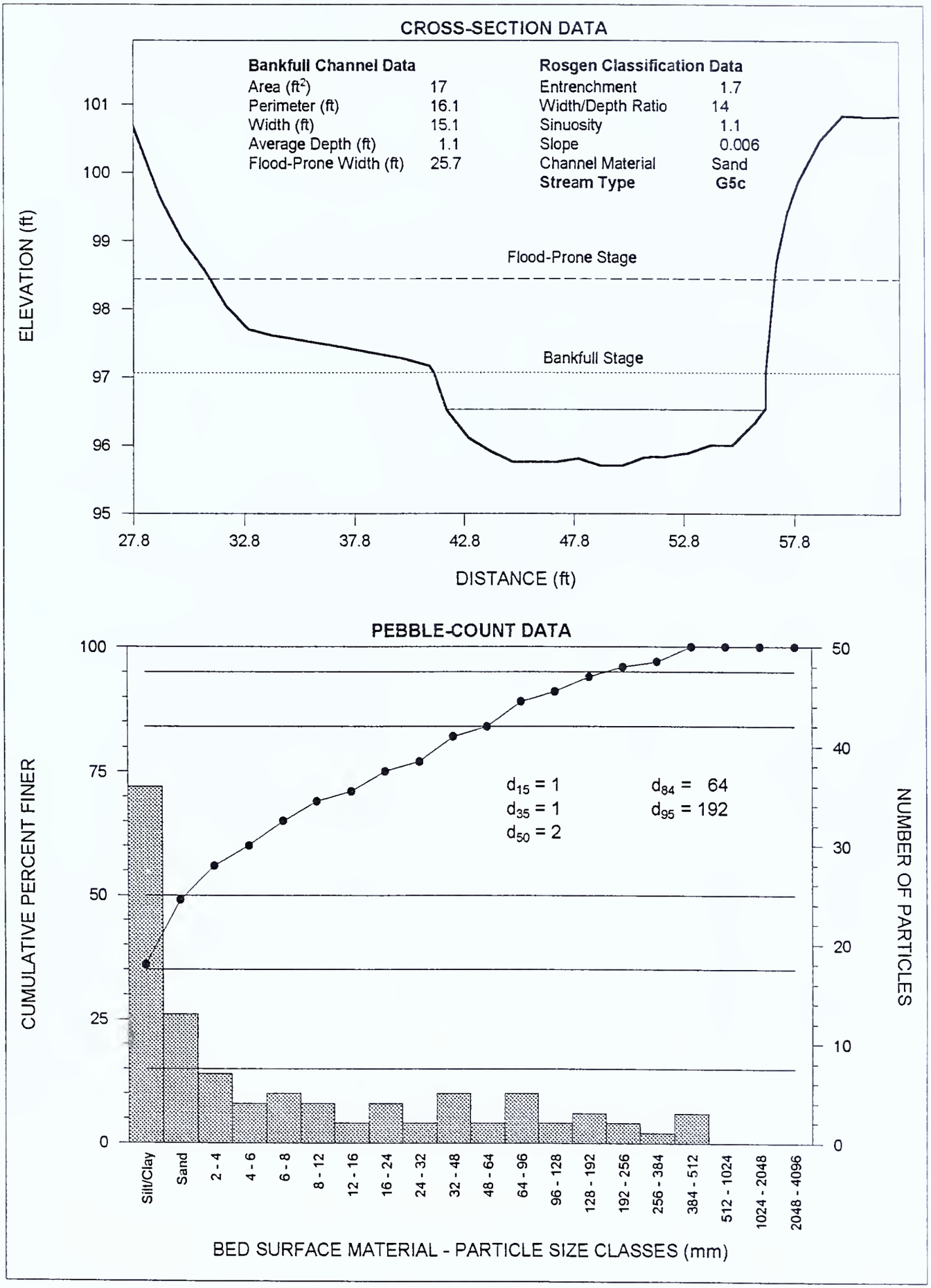


Figure A21. Cross-Section and Pebble Count Data From Letort Spring Run

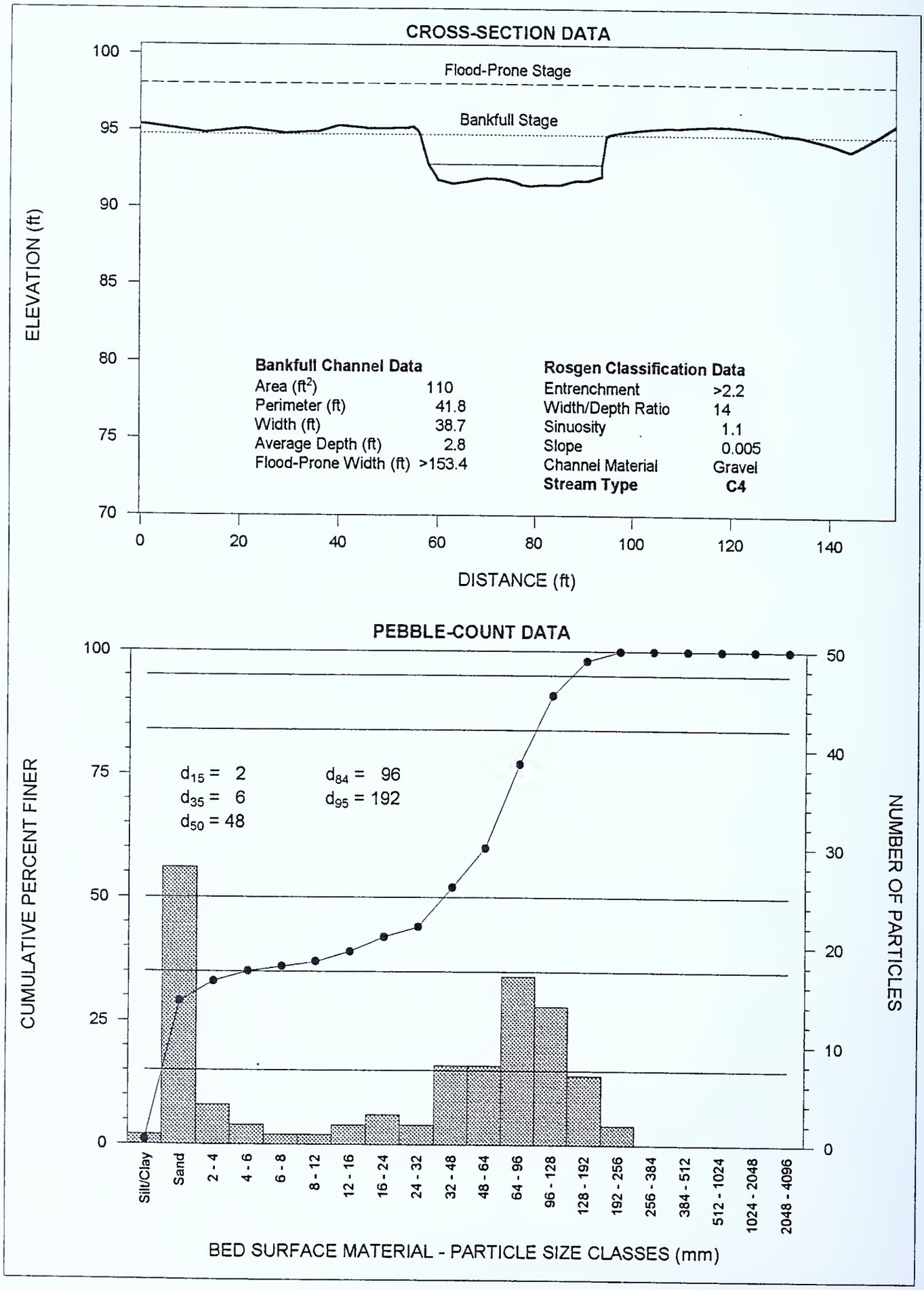


Figure A22. Cross-Section and Pebble Count Data From Mountain Creek

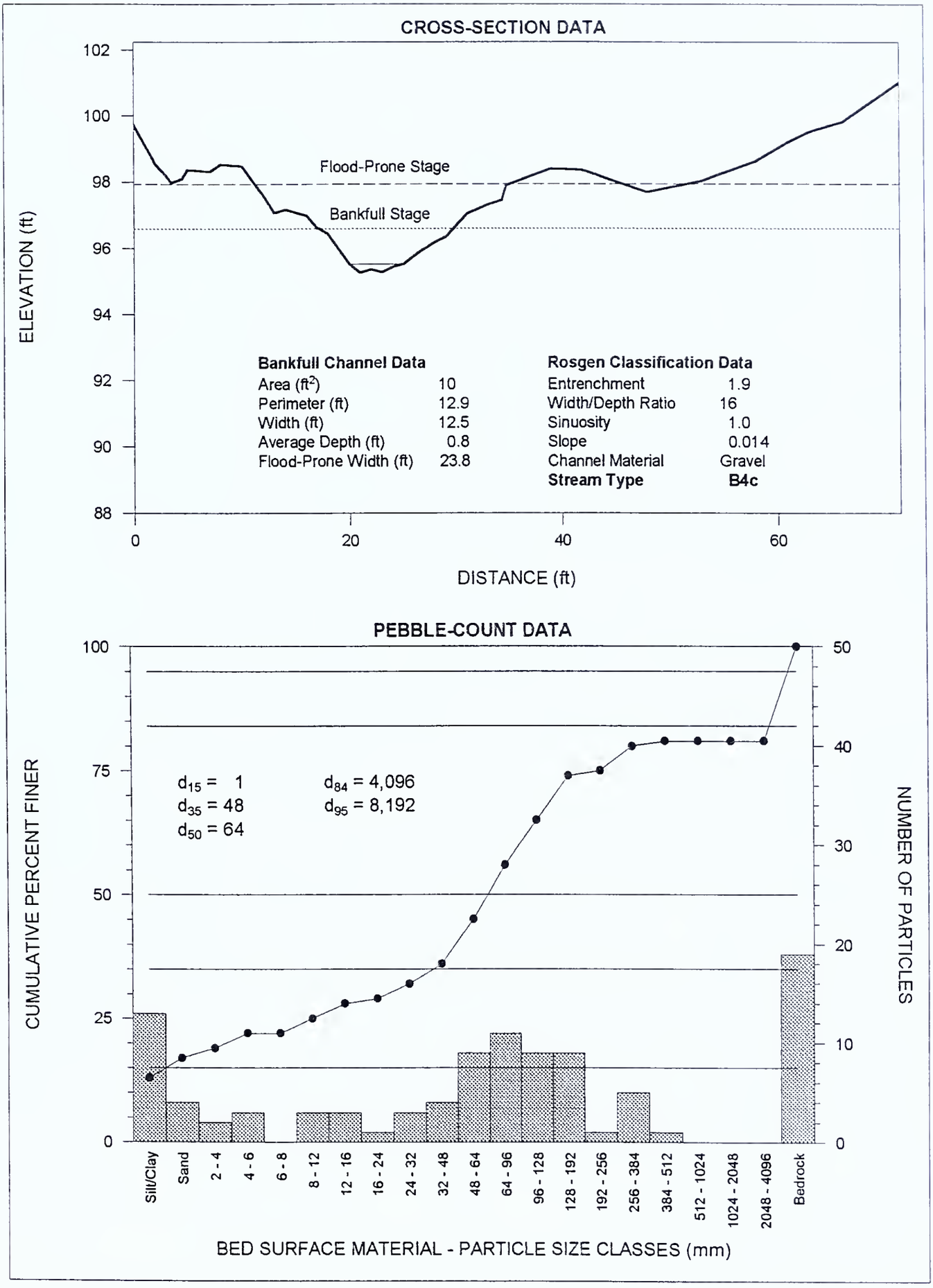


Figure A23. Cross-Section and Pebble Count Data From Murray Run

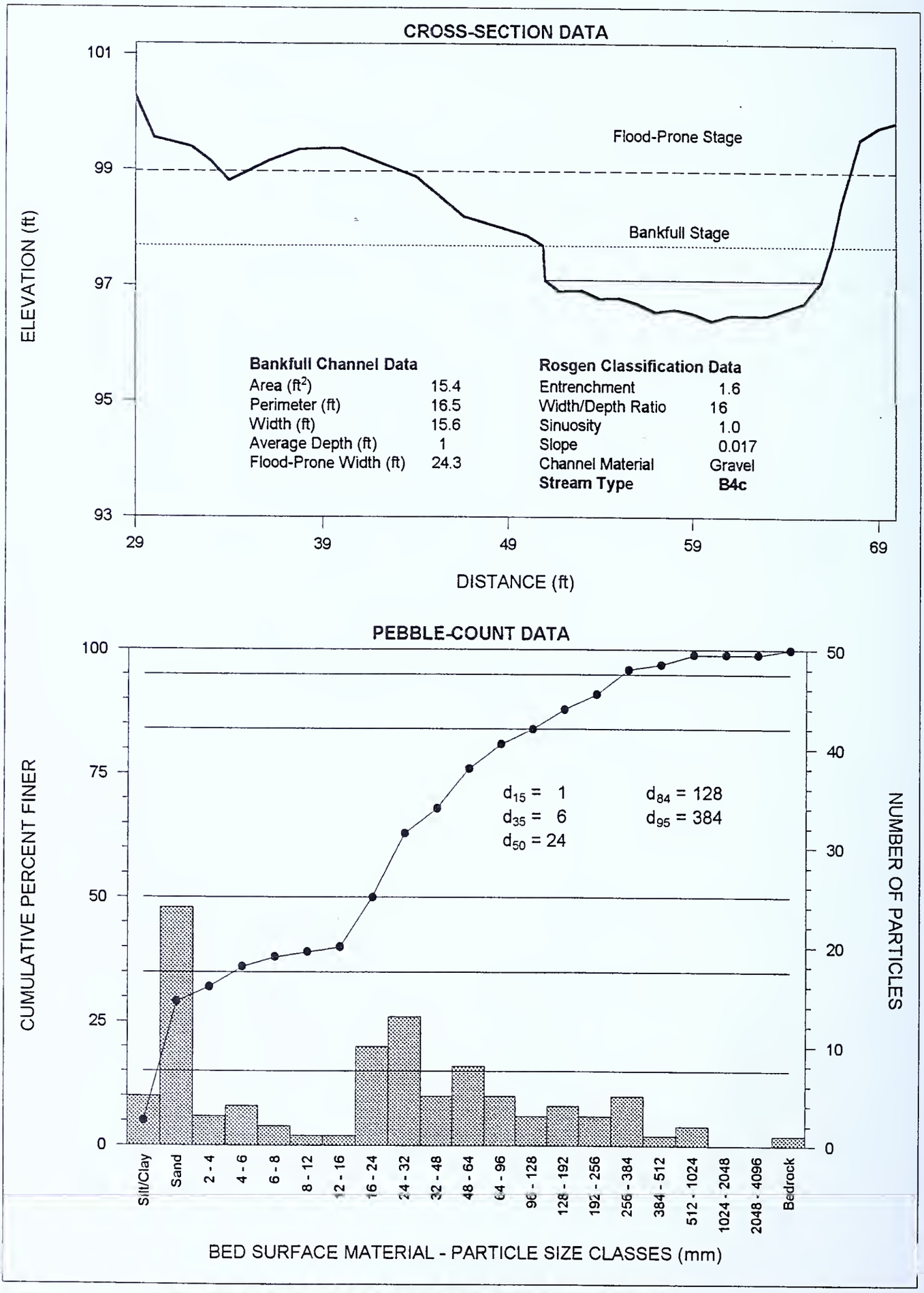


Figure A24. Cross-Section and Pebble Count Data From Pequea Creek

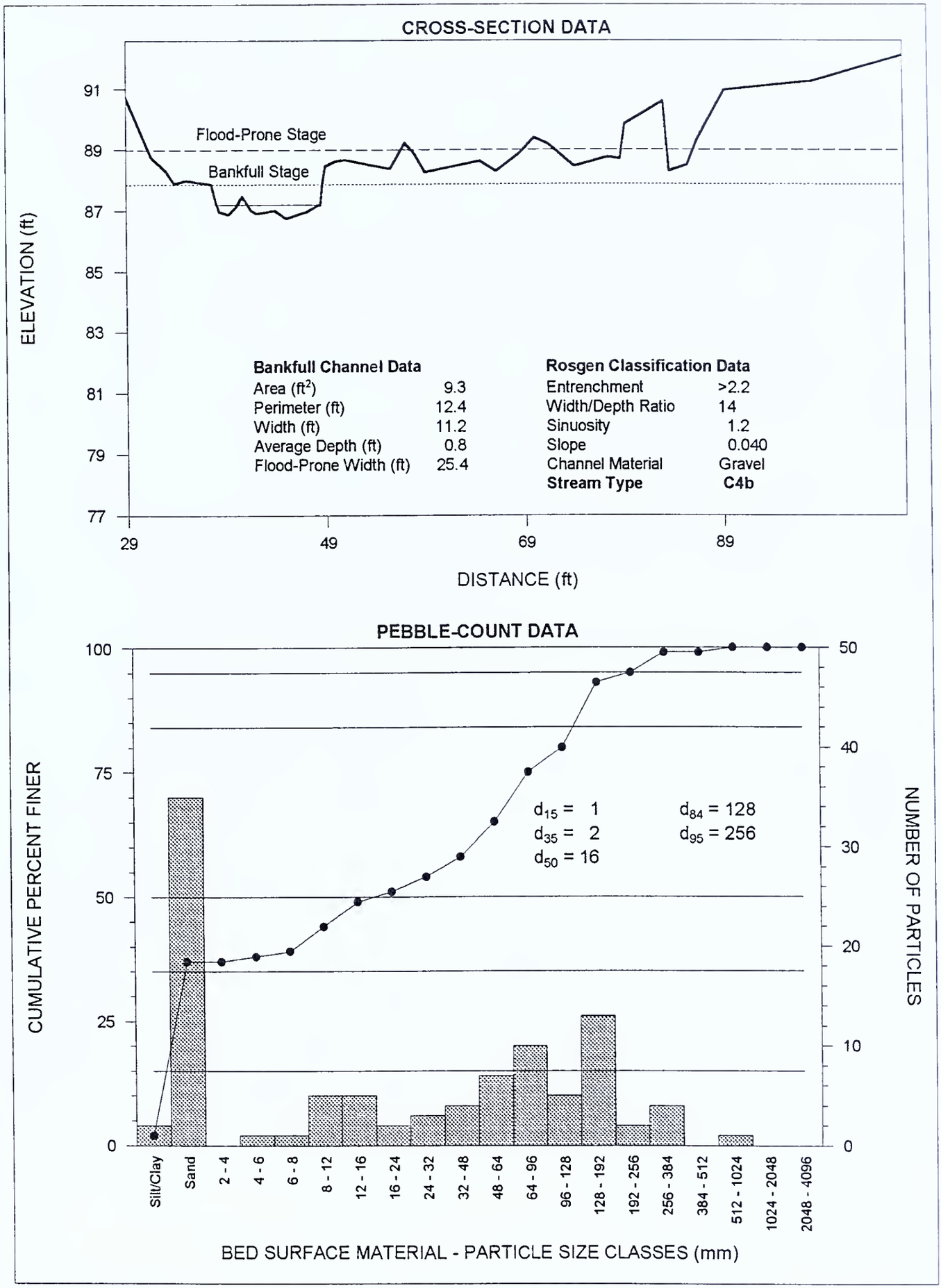
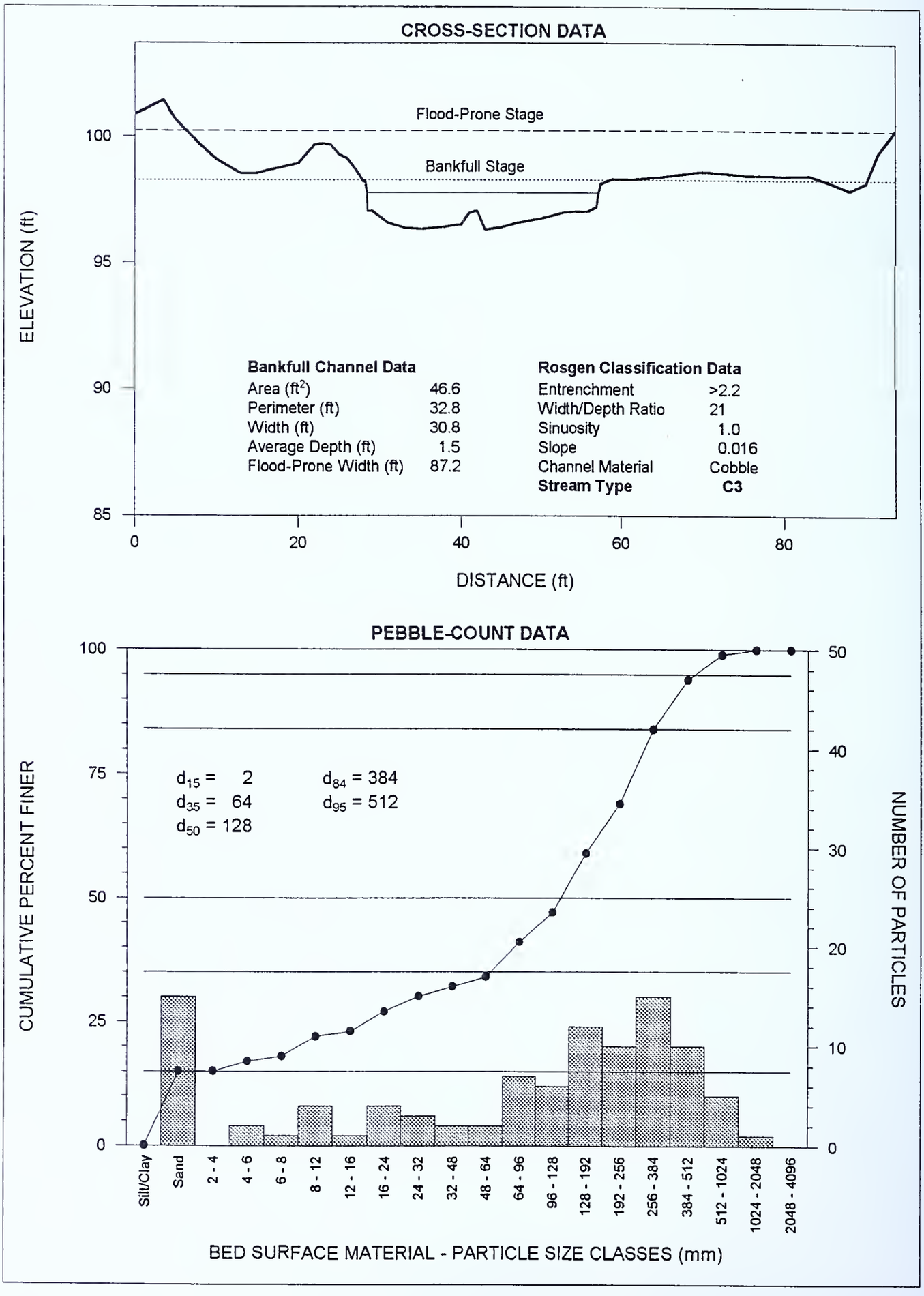


Figure A25. Cross-Section and Pebble Count Data From Rice Run



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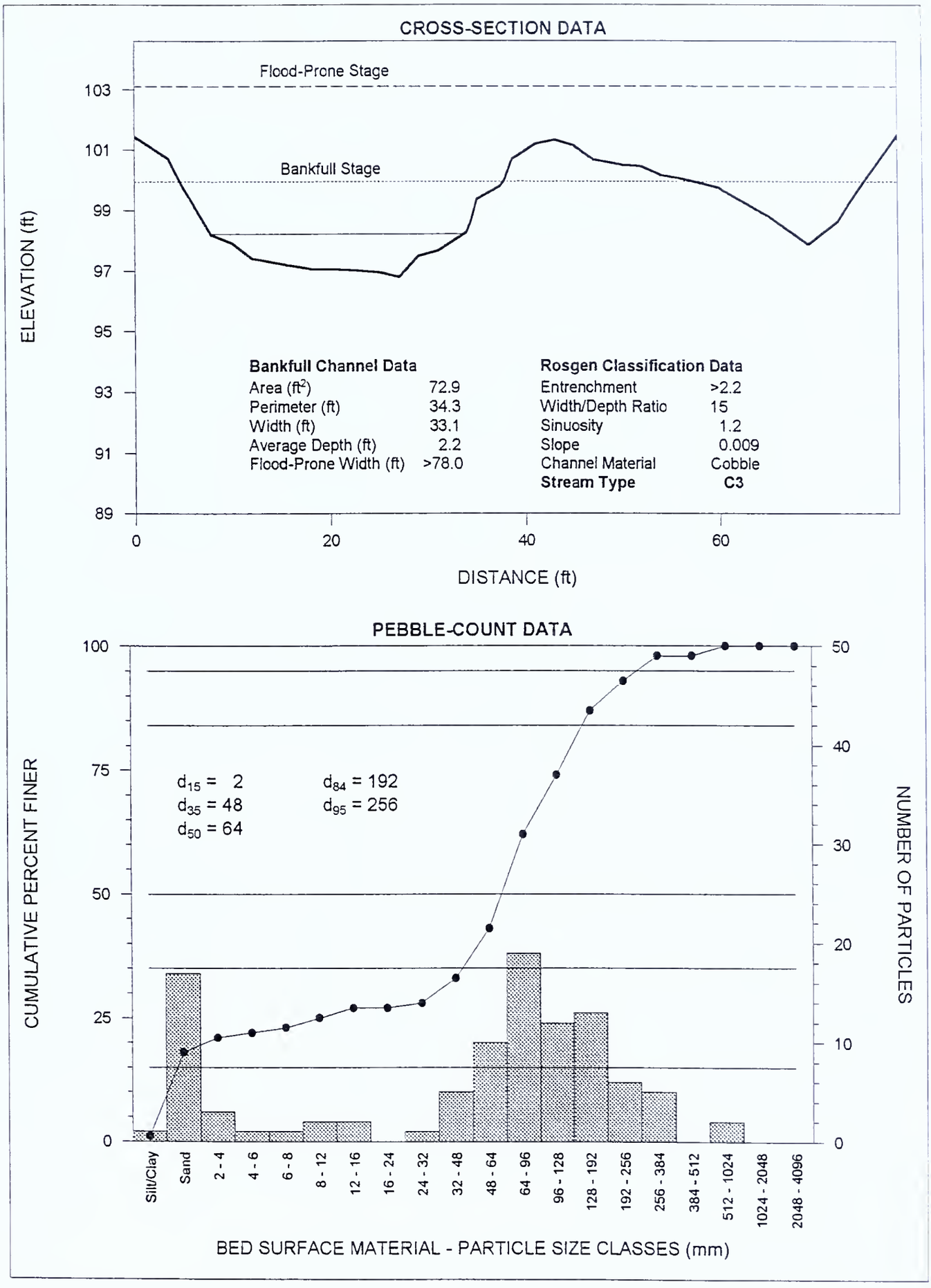

Figure A27. Cross-Section and Pebble Count Data From Standing Stone Creek

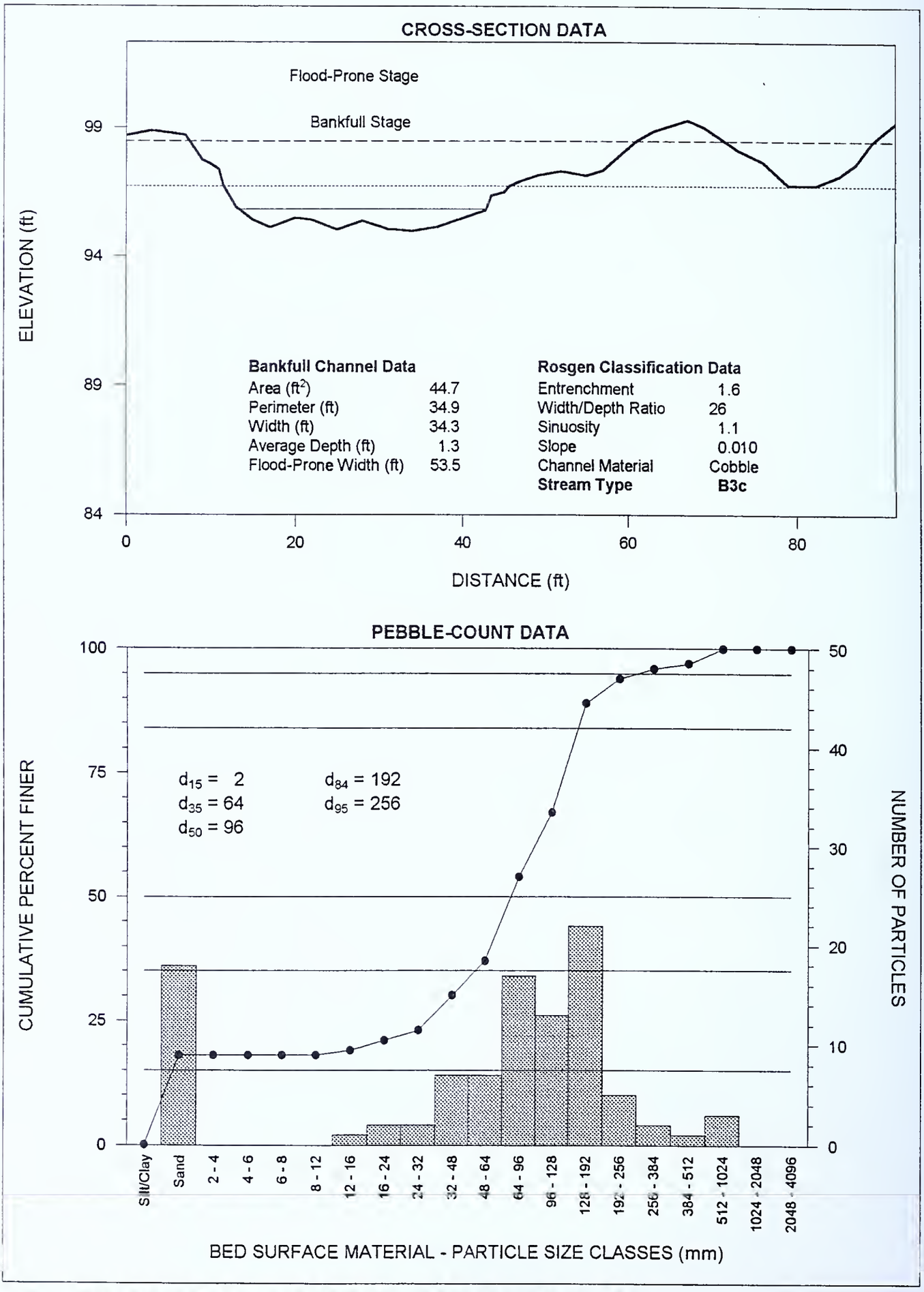

Figure A28. Cross-Section and Pebble Count Data From Tipton Run

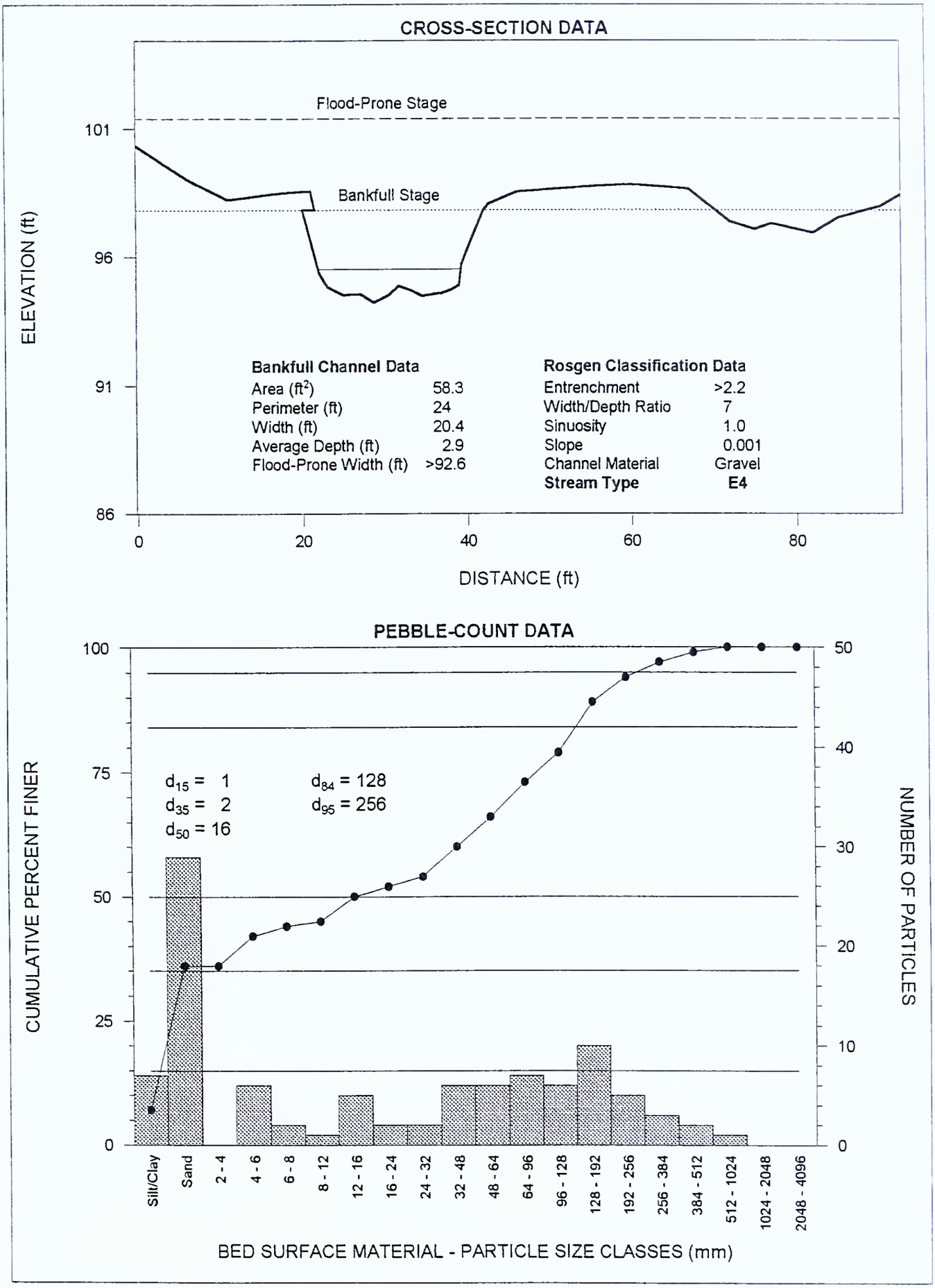

Figure A29. Cross-Section and Pebble Count Data From Toms Run (Lower)

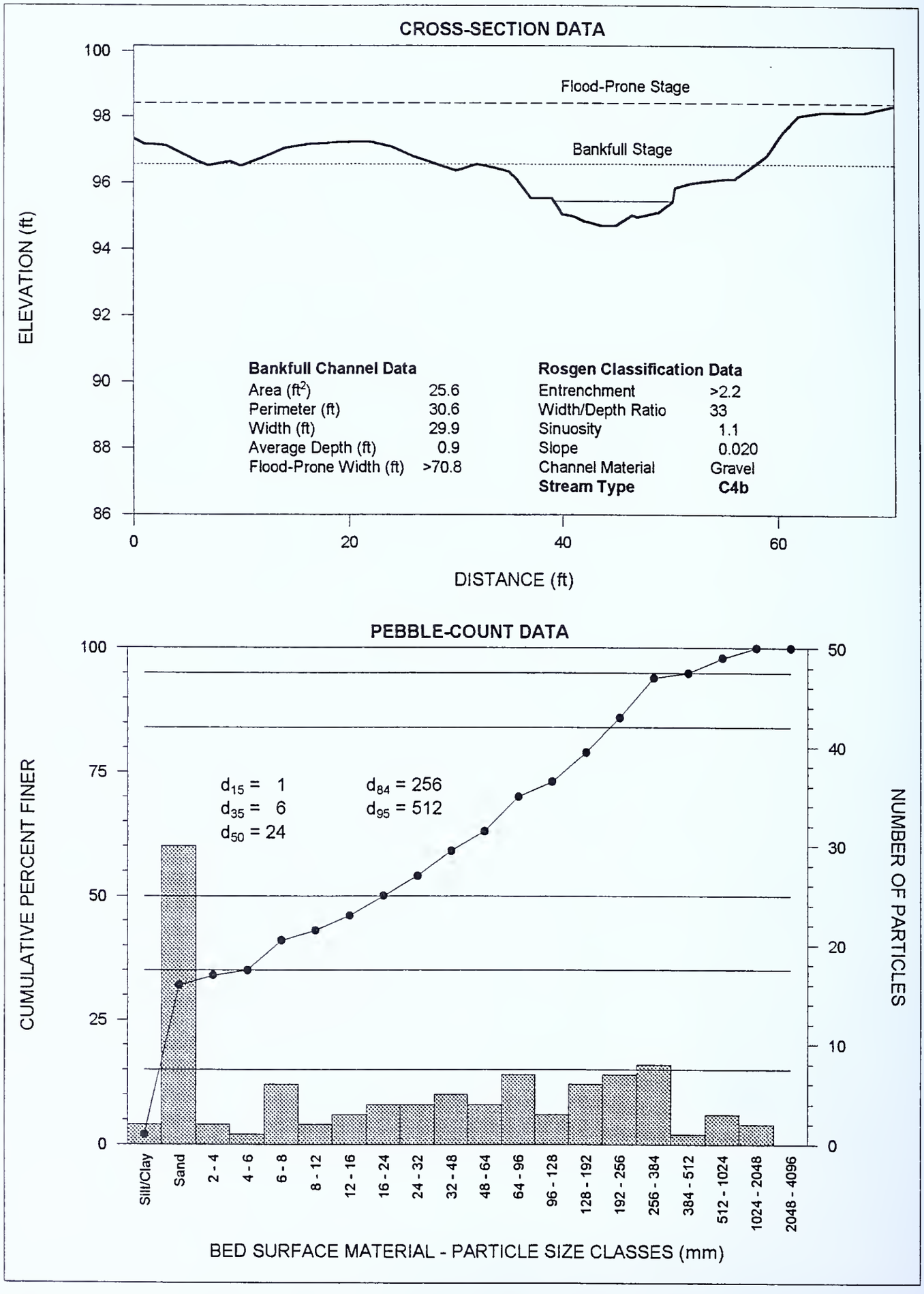

Figure A30. Cross-Section and Pebble Count Data From Toms Run (Upper)

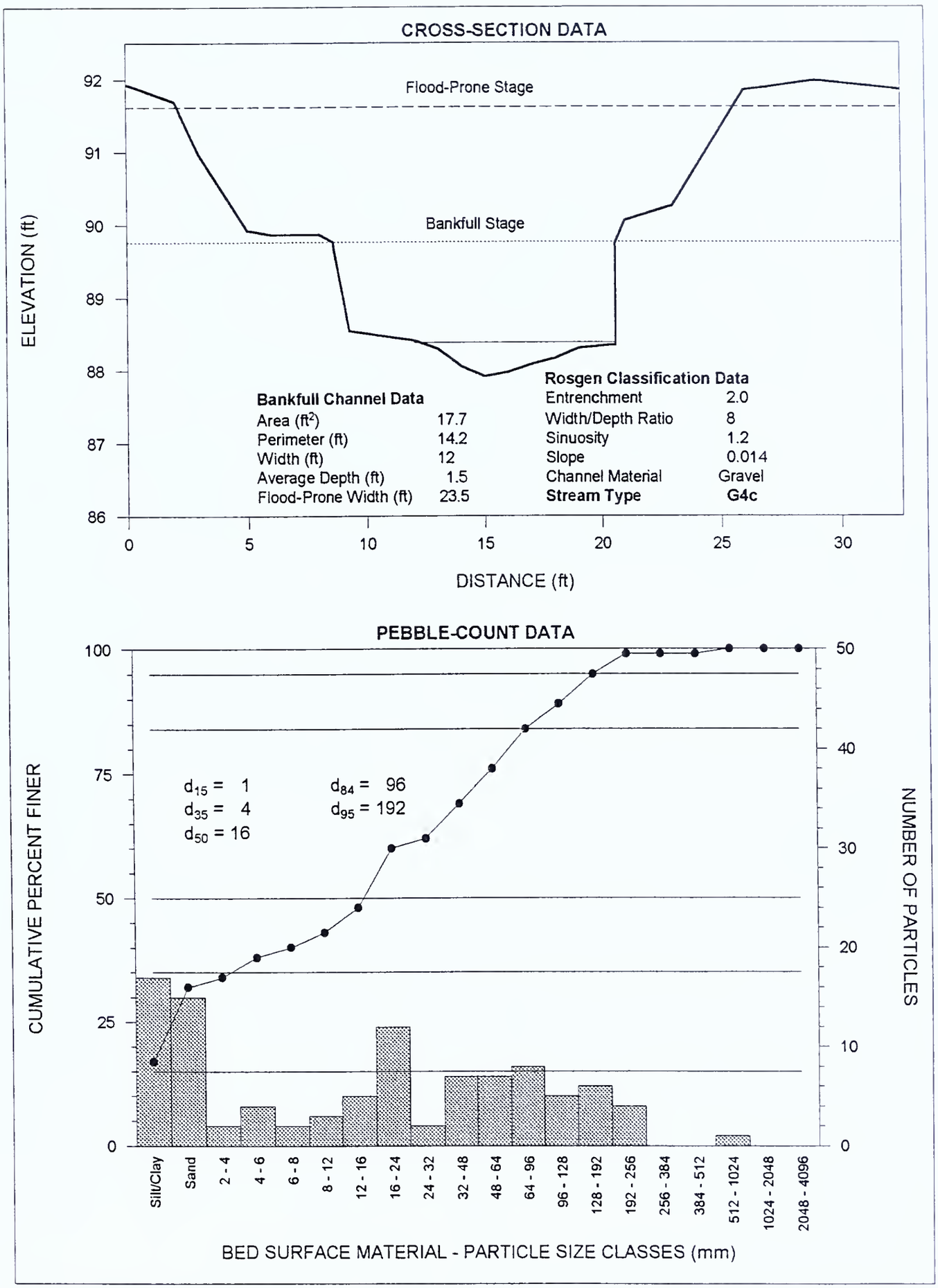

Figure A31. Cross-Section and Pebble Count Data From Unnamed Tributary to East Branch Codorus Creek

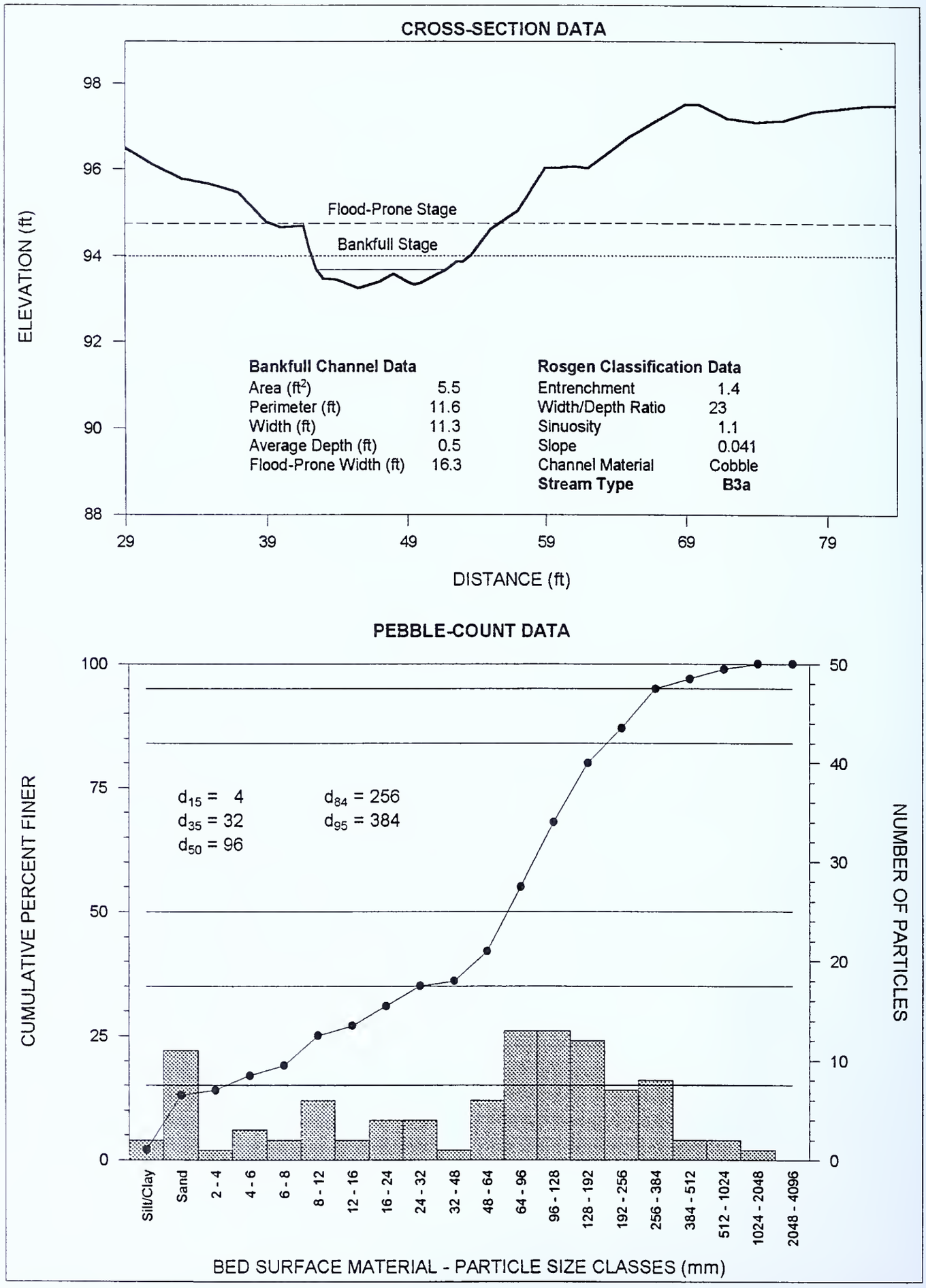

Figure A32. Cross-Section and Pebble Count Data From Unnamed Tributary to Harveys Creek

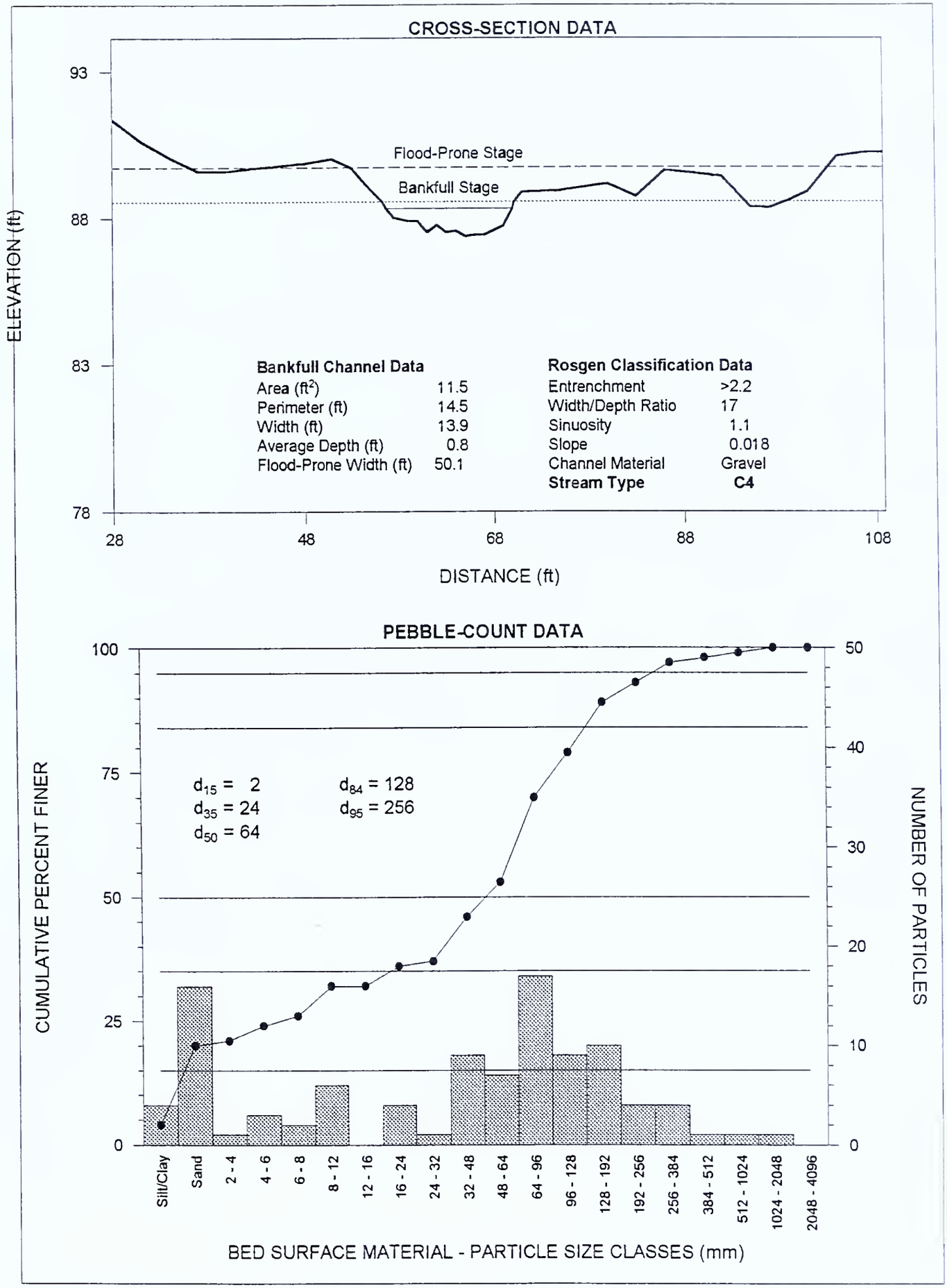

Figure A33. Cross-Section and Pebble Count Data From Unnamed Tributary to Roaring Brook

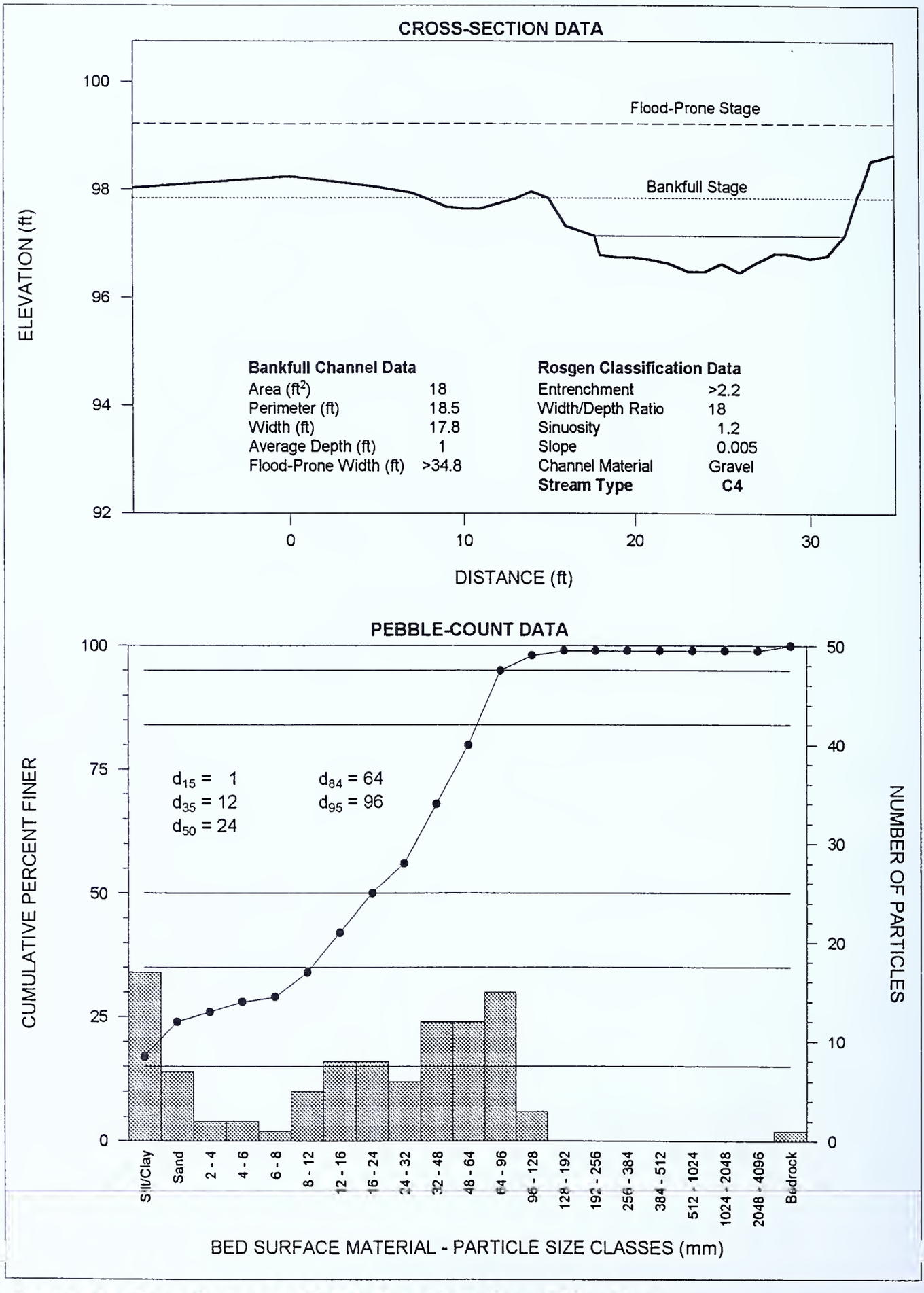

Figure A34. Cross-Section and Pebble Count Data From Willow Run

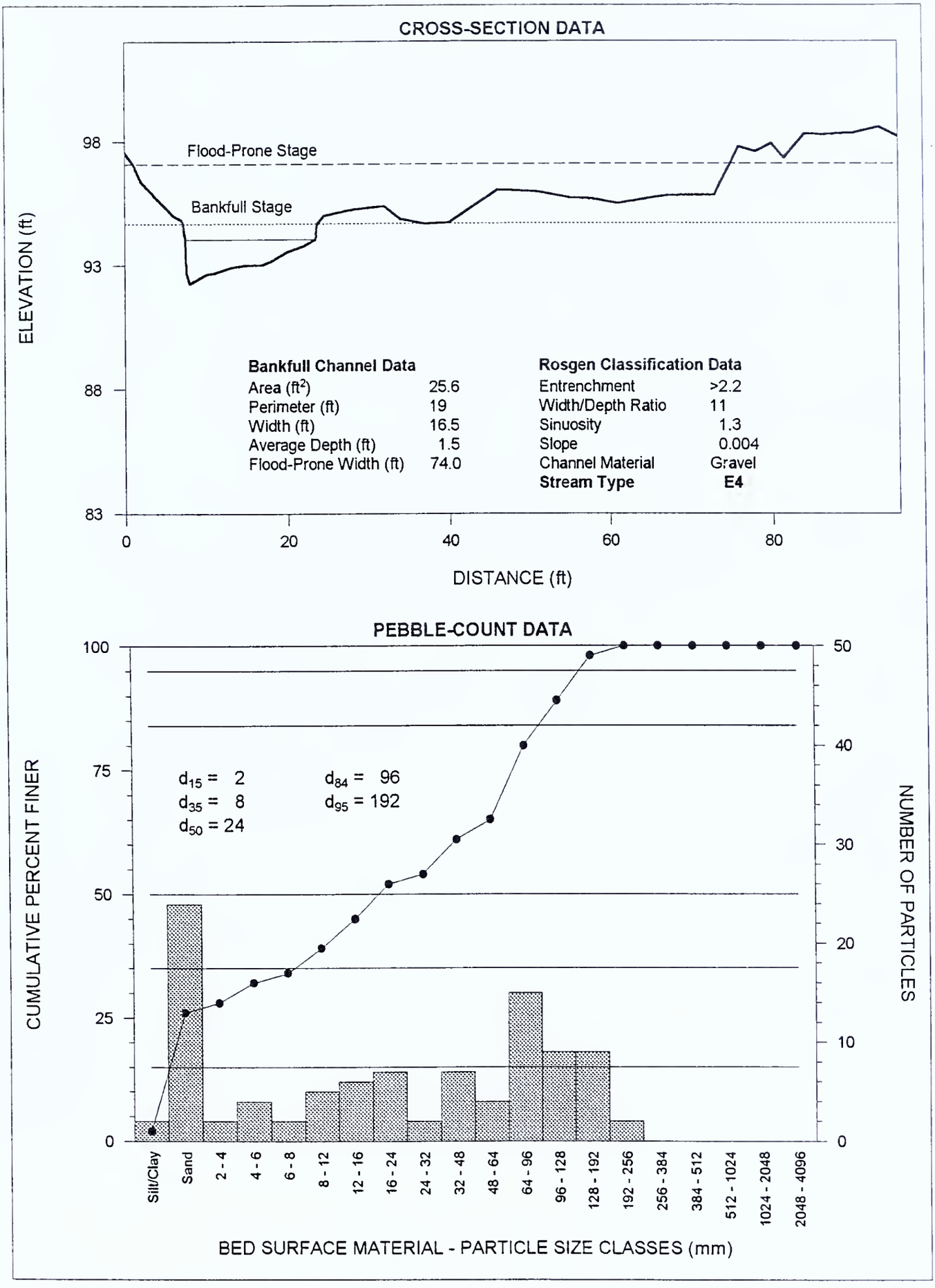

Figure A35. Cross-Section and Pebble Count Data From White Deer Creek

Appendix B

Stream Channel Morphology and Chemical Water Quality Data

Sample Site	Elevation (ft)	Drainage Area (mi^2)	Stream Order (1:24,000)	Bankfull Width (ft)	Mean Bankfull Depth (ft)	Bankfull Channel Area (ft)	Bankfull Perimeter (ft)	Entrenchment Ratio	Bankfull Width/Depth Ratio	Sinuosity	Slope	d15 Particle Size (mm)
ASPH	1,360	13.41	3	46.9	1.7	80.8	47.9	1.8	28	1.1	0.020	2
BALD	1,300	1.95	2	21.3	0.7	15.8	21.7	1.4	30	1.1	0.029	2
CORK	1,300	2.36	1	10.8	0.5	5.8	11.1	2.0	22	1.2	0.019	8
DEEP	1,240	2.26	1	22.8	0.9	20.8	23.4	1.4	25	1.1	0.036	16
DWMN	1,210	1.63	2	19.7	0.9	16.9	21.0	4.5	22	1.4	0.029	2
EBCC	590	12.37	3	17.9	1.4	25.4	19.3	1.7	13	1.0	0.002	1
EBLR	1,670	14.19	2	21.3	1.3	28.4	22.4	3.8	16	1.0	0.010	2
EBRB	1,700	6.19	2	27.0	1.6	42.1	29.1	1.3	17	1.0	0.019	32
GAZZ	1430	5.91	3	20.8	0.8	17.6	21.5	1.4	26	1.4	0.008	1
GRLE	845	2.84	1	21.4	1.5	33.0	23.0	4.5	14	1.4	0.014	1
GRNL	1,440	1.78	2	16.2	0.6	10.5	16.5	1.3	27	1.5	0.014	1
GRNU	1,560	1.03	2	15.5	0.5	8.4	16.6	1.3	31	1.1	0.012	1
HAML	430	17.26	3	25.9	1.3	34.7	26.7	1.3	20	1.1	0.003	1
HAMU	470	8.63	2	12.3	1.1	13.9	13.5	1.7	11	1.0	0.003	1
HARV	1,090	16.58	2	32.7	1.4	46.6	34.1	2.0	23	1.2	0.005	1
HORS	1,960	0.45	1	8.0	1.0	8.0	8.9	4.5	8	1.2	0.025	1
HUTT	1,800	1.23	2	11.0	0.8	9.3	12.1	2.8	14	1.1	0.040	2
IRON	805	2.36	2	18.6	0.9	16.2	19.6	4.5	21	1.1	0.019	1
LEBO	1,200	9.39	3	34.3	1.4	49.7	35.1	2.9	25	1.2	0.015	8
LMOR	1,700	3.12	2	11.6	0.7	8.6	12.6	2.0	17	1.2	0.027	2
LTRT	460	2.03	1	15.1	1.1	17.0	16.1	1.7	14	1.1	0.006	1
MNTN	810	21.61	3	38.7	2.8	110.0	41.8	4.5	14	1.1	0.005	2
MURY	860	3.35	1	12.5	0.8	10.0	12.9	1.9	16	1.0	0.014	1
PEQU	620	1.86	2	15.6	1.0	15.4	16.5	1.6	16	1.0	0.017	1
RICE	1,700	1.23	1	11.2	0.8	9.3	12.4	2.3	14	1.2	0.040	1
SIXM	1,405	18.30	3	30.8	1.5	46.6	32.8	2.8	21	1.0	0.016	2
STSN	960	15.27	3	33.1	2.2	72.9	34.3	4.5	15	1.2	0.009	2
TIPT	1,160	16.36	2	34.3	1.3	44.7	34.9	1.6	26	1.1	0.010	2
TOML	900	7.46	1	20.4	2.9	58.3	24.0	4.5	7	1.0	0.001	1
TOMU	1,200	3.41	1	29.9	0.9	25.6	30.6	2.4	33	1.1	0.020	1
UEBC	660	1.34	2	12.0	1.5	17.7	14.2	2.0	8	1.2	0.014	1
UHAR	1,100	0.50	1	11.3	0.5	5.5	11.6	1.4	23	1.1	0.041	4
URRB	1,660	4.62	2	13.9	0.8	11.5	14.5	3.6	17	1.1	0.018	2
WILL	610	6.56	1	17.8	1.0	18.0	18.5	4.5	18	1.2	0.005	1
WTDR	1420	6.88	2	16.5	1.5	25.6	19.0	4.5	11	1.3	0.004	2

Sample Site	d35 Particle Size (mm)	d50 Particle Size (mm)	d84 Particle Size (mm)	d95 Particle Size (mm)	Percent Pool	Percent Run	Percent Riffle	Percent Silt/Clay	Percent Sand	Percent Gravel	Percent Cobble	Percent Boulder	Percent Bedrock
ASPH	64	96	256	512	23	13	64	0	15	19	51	15	0
BALD	32	64	128	256	30	10	60	0	16	30	48	6	0
CORK	24	48	128	256	28	0	72	2	8	47	39	4	0
DEEP	64	128	384	1,024	35	4	60	2	2	29	38	29	0
DWMN	6	32	128	192	0	68	32	0	30	30	37	3	0
EBCC	4	12	64	256	69	7	24	17	15	48	14	6	0
EBLR	48	96	192	384	36	30	35	0	18	23	47	12	0
EBRB	96	192	4,096	8,192	36	50	14	2	8	11	34	23	22
GAZZ	4	24	96	192	54	8	38	12	19	41	27	1	0
GRLE	32	64	192	256	46	0	54	13	17	15	52	3	0
GRNL	2	48	128	256	37	10	53	4	32	24	37	3	0
GRNU	2	16	128	256	64	0	36	17	17	35	29	2	0
HAML	2	6	64	128	34	49	17	22	14	51	12	1	0
HAMU	1	2	24	64	31	51	18	29	27	41	3	0	0
HARV	12	32	192	512	29	39	31	5	22	28	32	13	0
HORS	2	2	64	256	56	0	44	8	52	25	10	5	0
HUTT	6	16	192	512	27	0	73	0	29	35	24	12	0
IRON	2	6	96	128	51	0	49	3	32	41	22	2	0
LEBO	64	96	192	256	21	38	41	0	14	19	63	4	0
LMOR	16	48	128	256	22	0	78	3	20	32	40	5	0
LTRT	1	2	64	192	24	29	47	36	13	35	12	4	0
MNTN	6	48	96	192	3	64	33	1	28	31	40	0	0
MURY	48	64	4,096	8,192	59	28	14	13	4	28	30	6	19
PEQU	6	24	128	384	50	0	50	5	24	47	15	8	1
RICE	2	16	128	256	48	0	52	2	35	28	30	5	0
SIXM	64	128	384	512	0	70	30	0	15	19	35	31	0
STSN	48	64	192	256	28	30	42	1	17	25	50	7	0
TIPT	64	96	192	256	27	28	45	0	18	19	57	6	0
TOML	2	16	128	256	0	72	28	7	29	30	28	6	0
TOMU	6	24	256	512	44	0	56	2	30	31	23	14	0
UEBC	4	16	96	192	30	24	46	17	15	44	23	1	0
UHAR	32	96	256	384	23	0	77	2	11	29	45	13	0
URRB	24	64	128	256	40	42	18	4	16	33	40	7	0
WILL	12	24	64	96	62	9	29	17	7	56	19	0	1
WTDR	8	24	96	192	16	42	43	2	24	39	35	0	0

Sample Site	Conductivity (umhos)	Water Temperature (C)	Dissolved Oxygen (mg/l)	pH	Alkalinity as $CaCO_3$ (mg/l)	Acidity as $CaCO_3$ (mg/l)
ASPH	48	10.3	9.55	6.55	18	8
BALD	29	10.5	9.25	6.25	8	8
CORK	76	9.2	7.73	6.85	18	2
DEEP	32	6.5	9.55	6.60	8	4
DWMN	30	14.1	9.42	5.50	2	16
EBCC	132	15.8	8.28	6.90	20	2
EBLR	50	10.2	8.42	6.55	10	2
EBRB	25	9.8	8.48	4.95	2	4
GAZZ	224	10.5	8.76	7.25	50	4
GRLE	23	12.3	7.92	5.75	2	6
GRNL	75	12.8	7.84	6.60	18	8
GRNU	61	14.2	7.54	6.40	12	8
HAML	465	10.9	9.28	8.05	184	4
HAMU	522	13.4	8.42	7.65	196	10
HARV	89	10.4	7.96	6.70	12	2
HORS	129	12.3	7.93	6.25	8	8
HUTT	36	10.2	8.19	6.20	12	10
IRON	41	13.3	9.33	6.70	14	6
LEBO	41	11.3	9.47	6.55	10	8
LMOR	38	12.1	9.63	6.50	12	6
LTRT	496	9.2	8.76	7.55	212	10
MNTN	28	17.0	9.17	6.35	8	8
MURY	81	12.2	8.43	7.00	26	6
PEQU	170	12.1	8.55	7.30	34	2
RICE	46	10.4	9.47	6.55	20	8
SIXM	37	12.3	8.79	6.35	10	6
STSN	21	13.5	7.46	7.02	14	10
TIPT	40	11.8	7.99	6.30	8	6
TOML	28	17.1	8.85	6.25	6	10
TOMU	32	14.7	8.91	5.65	2	14
UEBC	175	13.3	8.56	7.05	28	4
UHAR	67	8.4	8.20	6.75	10	4
URRB	46	9.5	8.31	6.20	10	4
WILL	175	10.7	9.47	7.50	78	4
WTDR	19	10.9	9.52	6.30	8	6

Appendix C

Benthic Macroinvertebrate Data

Class: Order	Family	Family/Genus	Tolerance	Trophic Guild	ASPH	BALD	CORK	DEEP
Insecta: Coleoptera	Elmidae	*Optioservus*	4	SC		2		
		Oulimnius	5	SC				1
		Promoresia	2	SC				
		Stenelmis	5	SC				
	Psephenidae	*Psephenus*	4	SC	1			
		Ectopria	5	SC	1			1
	Ptilodactylidae	*Anchytarsus*	5	SH				
Diptera	Athericidae	*Atherix*	2	P				5
	Ceratopogonidae	*Bezzia*	6	P				1
	Chironomidae	Chironomidae	7	CG	2	14	2	1
	Empididae	*Hemerodromia*	6	P				
	Simuliidae	Simuliidae	6	FC				
	Tabanidae	*Tabanus*	5	P			1	
	Tipulidae	*Antocha*	3	CG			2	
		Dicranota	3	P	1	1		
		Hexatoma	2	P	3	2		2
		Limonia	6	SH				
		Tipula	4	SH				
Ephemeroptera	Ameletidae	*Ameletus*	0	CG				
	Baetidae	*Acentrella*	4	CG	1			
		Baetis	6	CG	12	2		
		Centroptilum	2	CG				
		Cloeon	4	CG				
	Baetiscidae	*Baetisca*	4	CG				
	Ephemerellidae	*Ephemerella*	1	SC			27	6
		Eurylophella	4	SC				
		Serratella	2	SC	7			
	Ephemeridae	*Ephemera*	2	CG				
	Heptageniidae	*Epeorus*	0	CG				
		Heptagenia	4	SC	2	7		
		Leucrocuta	1	SC				
		Rhithrogena	0	CG				15
		Stenacron	4	SC				
		Stenonema	3	SC	7	8	3	2
	Isonychiidae	*Isonychia*	2	FC				
	Leptophlebiidae	*Paraleptophlebia*	1	CG	4	1	6	1
	Tricorythidae	*Tricorythodes*	4	CG				
Megaloptera	Corydalidae	*Nigronia*	2	P	2		2	
	Sialidae	*Sialis*	4	P				
Odonata	Aeshnidae	*Boyeria*	2	P	1			
	Gomphidae	*Lanthus*	5	P	1	1		
		Stylogomphus albistylus	4	P				
Plecoptera	Chloroperlidae	*Alloperla*	0	CG	3	10		2
		Haploperla	0	P				2
		Sweltsa	0	P				2
	Leuctridae	*Leuctra*	0	SH				
	Peltoperlidae	*Peltoperla*	2	SH				
		Tallaperla	0	SH	1	4		4
	Perlidae	*Acroneuria*	0	P			2	1
		Agnetina	2	P				1
		Eccoptura	2	P	3			
		Paragnetina	1	P	2			
	Perlodidae	*Cultus*	2	P				
		Diploperla	2	P				
		Hydroperla	1	P	5	8		2
		Isoperla	2	P	1	4	2	
		Remenus	2	P				
	Pteronarcyidae	*Pteronarcys*	0	SH	4	16		2
	Taeniopterygidae	*Strophopteryx*	3	SH				
		Taeniopteryx	2	SH			4	

Class: Order	Family	Family/Genus	Tolerance	Trophic Guild	ASPH	BALD	CORK	DEEP
Trichoptera	Brachycentridae	*Brachycentrus*	1	FC				
	Glossosomatidae	*Agapetus*	0	SC				
		Glossosoma	0	SC			1	1
		Protoptila	1	SC				
	Hydropsychidae	*Cheumatopsyche*	5	FC	5	2	11	3
		Diplectrona	0	FC			6	
		Homoplectra	0	FC				
		Hydropsyche	4	FC	7	6	6	12
		Potamyia flava	5	FC		1		3
	Lepidostomatidae	*Theliopsyche*	1	SH				
	Odontoceridae	*Psilotreta*	0	SC				
	Philopotamidae	*Chimarra*	4	FC				
		Dolophilodes	0	FC	21	17	21	24
	Polycentropodidae	*Neureclipsis*	7	FC				2
		Polycentropus	6	FC				
	Psychomyiidae	*Lype diversa*	2	CG				
	Rhyacophilidae	*Rhyacophila*	1	P	3		4	
Rhynchobdellida	Glossiphonidae	*Batrachobdella*	6	P				
Crustacea: Amphipoda	Gammaridae	*Gammarus*	6	SH				
Decapoda	Cambaridae	*Cambarus*	6	CG		1		
Isopoda	Asellidae	*Caecidotea*	8	SH				
		Lirceus	8	CG				
Gastropoda: Gastropoda	Pleuroceridae	*Leptoxis*	6	SC				

Class: Order	Family	Family/Genus	DWMN	EBCC	EBLR	EBRB	GAZZ	GRLE
Insecta: Coleoptera	Elmidae	*Optioservus*	6	8	4	1	13	
		Oulimnius					6	
		Promoresia			1	2	2	
		Stenelmis						
	Psephenidae	*Psephenus*		1	2	4		
		Ectopria				1	1	
	Ptilodactylidae	*Anchytarsus*						
Diptera	Athericidae	*Atherix*		4	2	2		
	Ceratopogonidae	*Bezzia*					2	
	Chironomidae	Chironomidae	1	5	4	4	14	8
	Empididae	*Hemerodromia*						
	Simuliidae	Simuliidae					1	
	Tabanidae	*Tabanus*						
	Tipulidae	*Antocha*						
		Dicranota				1	1	1
		Hexatoma			5	6	3	1
		Limonia						
		Tipula						
Ephemeroptera	Ameletidae	*Ameletus*						
	Baetidae	*Acentrella*		8	2			
		Baetis					5	
		Centroptilum		3				
		Cloeon						
	Baetiscidae	*Baetisca*						
	Ephemerellidae	*Ephemerella*			19		1	
		Eurylophella						
		Serratella				3		
	Ephemeridae	*Ephemera*						
	Heptageniidae	*Epeorus*						
		Heptagenia						
		Leucrocuta						
		Rhithrogena						
		Stenacron						
		Stenonema		6	15	15	3	8
	Isonychiidae	*Isonychia*		8	6			
	Leptophlebiidae	*Paraleptophlebia*			8	5	6	
	Tricorythidae	*Tricorythodes*						
Megaloptera	Corydalidae	*Nigronia*		3	1	6	2	2
	Sialidae	*Sialis*				1		
Odonata	Aeshnidae	*Boyeria*						
	Gomphidae	*Lanthus*		1		2		1
		Stylogomphus albistylus					1	
Plecoptera	Chloroperlidae	*Alloperla*					9	
		Haploperla						
		Sweltsa						
	Leuctridae	*Leuctra*						
	Peltoperlidae	*Peltoperla*						
		Tallaperla				4		
	Perlidae	*Acroneuria*		7	1	6	3	8
		Agnetina			5			
		Eccoptura	4			1		
		Paragnetina						
	Perlodidae	*Cultus*						
		Diploperla						
		Hydroperla						
		Isoperla		1	1	2		1
		Remenus				2		
	Pteronarcyidae	*Pteronarcys*			1	1		
	Taeniopterygidae	*Strophopteryx*						
		Taeniopteryx			6	10	1	

Class: Order	Family	Family/Genus	DWMN	EBCC	EBLR	EBRB	GAZZ	GRLE
Trichoptera	Brachycentridae	*Brachycentrus*						
	Glossosomatidae	*Agapetus*	1			11		
		Glossosoma		1				
		Protoptila				3		
	Hydropsychidae	*Cheumatopsyche*	4	13	2	1	7	2
		Diplectrona	3			8	2	
		Homoplectra						
		Hydropsyche		30	21	8	9	22
		Potamyia flava					2	25
	Lepidostomatidae	*Theliopsyche*						
	Odontoceridae	*Psilotreta*						
	Philopotamidae	*Chimarra*				1		
		Dolophilodes	2	2	7	6	4	25
	Polycentropodidae	*Neureclipsis*					3	1
		Polycentropus						
	Psychomyiidae	*Lype diversa*						
	Rhyacophilidae	*Rhyacophila*		1				
Rhynchobdellida	Glossiphonidae	*Batrachobdella*						
Crustacea: Amphipoda	Gammaridae	*Gammarus*						
Decapoda	Cambaridae	*Cambarus*					2	
Isopoda	Asellidae	*Caecidotea*						
		Lirceus						
Gastropoda: Gastropoda	Pleuroceridae	*Leptoxis*						

Class: Order	Family	Family/Genus	GRNL	GRNU	HAML	HAMU	HARV	HORS
Insecta: Coleoptera	Elmidae	*Optioservus*	1	3	22	8	6	
		Oulimnius						
		Promoresia		1				
		Stenelmis			4	3		
	Psephenidae	*Psephenus*						
		Ectopria						
	Ptilodactylidae	*Anchytarsus*						
Diptera	Athericidae	*Atherix*						
	Ceratopogonidae	*Bezzia*						
	Chironomidae	Chironomidae	7	6	3	34		11
	Empididae	*Hemerodromia*						
	Simuliidae	Simuliidae	1			2	2	
	Tabanidae	*Tabanus*		1				
	Tipulidae	*Antocha*				4		
		Dicranota						
		Hexatoma	1	1		2		
		Limonia						
		Tipula		1				
Ephemeroptera	Ameletidae	*Ameletus*		1				
	Baetidae	*Acentrella*					3	
		Baetis	12		8	15		
		Centroptilum						
		Cloeon						
	Baetiscidae	*Baetisca*						
	Ephemerellidae	*Ephemerella*						
		Eurylophella					2	
		Serratella	3		1			
	Ephemeridae	*Ephemera*		1				
	Heptageniidae	*Epeorus*						
		Heptagenia						
		Leucrocuta						
		Rhithrogena						
		Stenacron						
		Stenonema	4	13	10		21	
	Isonychiidae	*Isonychia*					17	
	Leptophlebiidae	*Paraleptophlebia*	8	6			1	
	Tricorythidae	*Tricorythodes*				1		
Megaloptera	Corydalidae	*Nigronia*	1	2	1		9	
	Sialidae	*Sialis*						
Odonata	Aeshnidae	*Boyeria*	1	2				
	Gomphidae	*Lanthus*					1	
		Stylogomphus albistylus	1					
Plecoptera	Chloroperlidae	*Alloperla*	2					
		Haploperla						
		Sweltsa						
	Leuctridae	*Leuctra*						
	Peltoperlidae	*Peltoperla*						
		Tallaperla	1					
	Perlidae	*Acroneuria*	6					
		Agnetina						
		Eccoptura					2	
		Paragnetina		10				
	Perlodidae	*Cultus*						
		Diploperla		3				
		Hydroperla						
		Isoperla	2					
		Remenus						
	Pteronarcyidae	*Pteronarcys*						
	Taeniopterygidae	*Strophopteryx*						
		Taeniopteryx					3	

Class: Order	Family	Family/Genus	GRNL	GRNU	HAML	HAMU	HARV	HORS
Trichoptera	Brachycentridae	*Brachycentrus*						
	Glossosomatidae	*Agapetus*						
		Glossosoma						
		Protoptila						
	Hydropsychidae	*Cheumatopsyche*	17	15			9	
		Diplectrona	4	4			1	
		Homoplectra						
		Hydropsyche	6	3	45	23	6	
		Potamyia flava		8	16			
	Lepidostomatidae	*Theliopsyche*						
	Odontoceridae	*Psilotreta*						
	Philopotamidae	*Chimarra*			1		21	
		Dolophilodes	15	11				
	Polycentropodidae	*Neureclipsis*						
		Polycentropus						
	Psychomyiidae	*Lype diversa*	2					
	Rhyacophilidae	*Rhyacophila*	1	4				
Rhynchobdellida	Glossiphonidae	*Batrachobdella*						
Crustacea: Amphipoda	Gammaridae	*Gammarus*				18		1
Decapoda	Cambaridae	*Cambarus*	1				2	
Isopoda	Asellidae	*Caecidotea*						2
		Lirceus						
Gastropoda: Gastropoda	Pleuroceridae	*Leptoxis*						

Class: Order	Family	Family/Genus	HUTT	IRON	LEBO	LMOR	LTRT	MNTN
Insecta: Coleoptera	Elmidae	*Optioservus*			2	1	6	
		Oulimnius				3	1	
		Promoresia		4				
		Stenelmis						1
	Psephenidae	*Psephenus*						
		Ectopria		2		1		
	Ptilodactylidae	*Anchytarsus*						
Diptera	Athericidae	*Atherix*			20	1		
	Ceratopogonidae	*Bezzia*						
	Chironomidae	Chironomidae	1	3	2	7	2	15
	Empididae	*Hemerodromia*						
	Simuliidae	Simuliidae		1	1			
	Tabanidae	*Tabanus*						
	Tipulidae	*Antocha*						
		Dicranota		2		1		2
		Hexatoma		9		5		10
		Limonia						
		Tipula	3	1	1		1	1
Ephemeroptera	Ameletidae	*Ameletus*						
	Baetidae	*Acentrella*						
		Baetis			26	8	2	1
		Centroptilum						
		Cloeon						
	Baetiscidae	*Baetisca*						
	Ephemerellidae	*Ephemerella*	15			1		1
		Eurylophella						
		Serratella			4			
	Ephemeridae	*Ephemera*						
	Heptageniidae	*Epeorus*						3
		Heptagenia			3	13		
		Leucrocuta			4			
		Rhithrogena						
		Stenacron						
		Stenonema		3	1	4		8
	Isonychiidae	*Isonychia*						
	Leptophlebiidae	*Paraleptophlebia*				1		
	Tricorythidae	*Tricorythodes*						
Megaloptera	Corydalidae	*Nigronia*		2				1
	Sialidae	*Sialis*						
Odonata	Aeshnidae	*Boyeria*						
	Gomphidae	*Lanthus*		5				
		Stylogomphus albistylus						
Plecoptera	Chloroperlidae	*Alloperla*						
		Haploperla						
		Sweltsa						
	Leuctridae	*Leuctra*						
	Peltoperlidae	*Peltoperla*						
		Tallaperla		3	3	8		
	Perlidae	*Acroneuria*						2
		Agnetina			2			
		Eccoptura		6	1			
		Paragnetina						
	Perlodidae	*Cultus*						
		Diploperla						
		Hydroperla			2	4		1
		Isoperla	6	1	3	4		
		Remenus						
	Pteronarcyidae	*Pteronarcys*		3	4	1		
	Taeniopterygidae	*Strophopteryx*						1
		Taeniopteryx						

Class: Order	Family	Family/Genus	HUTT	IRON	LEBO	LMOR	LTRT	MNTN
Trichoptera	Brachycentridae	*Brachycentrus*		1				1
	Glossosomatidae	*Agapetus*						
		Glossosoma			2			1
		Protoptila						
	Hydropsychidae	*Cheumatopsyche*				17		
		Diplectrona		11		1		3
		Homoplectra						
		Hydropsyche		15	4	9		10
		Potamyia flava		15		6		8
	Lepidostomatidae	*Theliopsyche*	6					
	Odontoceridae	*Psilotreta*						
	Philopotamidae	*Chimarra*						
		Dolophilodes		10	13	5		2
	Polycentropodidae	*Neureclipsis*						
		Polycentropus						
	Psychomyiidae	*Lype diversa*						
	Rhyacophilidae	*Rhyacophila*		2		3		1
Rhynchobdellida	Glossiphonidae	*Batrachobdella*						
Crustacea: Amphipoda	Gammaridae	*Gammarus*					63	
Decapoda	Cambaridae	*Cambarus*		1		1		1
Isopoda	Asellidae	*Caecidotea*						
		Lirceus					37	
Gastropoda: Gastropoda	Pleuroceridae	*Leptoxis*						

Class: Order	Family	Family/Genus	MURY	PEQU	RICE	SIXM	STSN	TIPT
Insecta: Coleoptera	**Elmidae**	*Optioservus*	1	3				
		Oulimnius		1				1
		Promoresia					2	
		Stenelmis						
	Psephenidae	*Psephenus*	1	1				
		Ectopria				2		3
	Ptilodactylidae	*Anchytarsus*						
Diptera	**Athericidae**	*Atherix*						
	Ceratopogonidae	*Bezzia*						
	Chironomidae	Chironomidae	12	1	3	5	6	8
	Empididae	*Hemerodromia*					1	
	Simuliidae	Simuliidae	13				4	1
	Tabanidae	*Tabanus*						
	Tipulidae	*Antocha*		6				
		Dicranota						
		Hexatoma		2	6	2	1	
		Limonia						
		Tipula						2
Ephemeroptera	**Ameletidae**	*Ameletus*						
	Baetidae	*Acentrella*	1	2				
		Baetis	4	2		21		
		Centroptilum						
		Cloeon						4
	Baetiscidae	*Baetisca*				1		
	Ephemerellidae	*Ephemerella*				2		
		Eurylophella						
		Serratella		1				
	Ephemeridae	*Ephemera*						
	Heptageniidae	*Epeorus*						
		Heptagenia						
		Leucrocuta			4			
		Rhithrogena						
		Stenacron						
		Stenonema	13	4	8		2	3
	Isonychiidae	*Isonychia*	1					3
	Leptophlebiidae	*Paraleptophlebia*	2		1			1
	Tricorythidae	*Tricorythodes*						
Megaloptera	**Corydalidae**	*Nigronia*	1			5	3	1
	Sialidae	*Sialis*	1					
Odonata	**Aeshnidae**	*Boyeria*						
	Gomphidae	*Lanthus*				4	1	
		Stylogomphus albistylus		1				1
Plecoptera	**Chloroperlidae**	*Alloperla*	4		4			
		Haploperla						
		Sweltsa						
	Leuctridae	*Leuctra*					4	
	Peltoperlidae	*Peltoperla*			2			
		Tallaperla		1		1		2
	Perlidae	*Acroneuria*	7			8		
		Agnetina						
		Eccoptura				9		1
		Paragnetina					2	
	Perlodidae	*Cultus*						
		Diploperla						
		Hydroperla						
		Isoperla	9		5			
		Remenus					2	
	Pteronarcyidae	*Pteronarcys*			19	3	1	
	Taeniopterygidae	*Strophopteryx*						
		Taeniopteryx						

Class: Order	Family	Family/Genus	MURY	PEQU	RICE	SIXM	STSN	TIPT
Trichoptera	Brachycentridae	*Brachycentrus*						
	Glossosomatidae	*Agapetus*						
		Glossosoma			1			
		Protoptila						
	Hydropsychidae	*Cheumatopsyche*	1	2	4	1		14
		Diplectrona	3				1	9
		Homoplectra						
		Hydropsyche		46	19	4	6	7
		Potamyia flava	3	7		3	12	3
	Lepidostomatidae	*Theliopsyche*						
	Odontoceridae	*Psilotreta*						
	Philopotamidae	*Chimarra*		6				
		Dolophilodes	21	4	5	21	24	41
	Polycentropodidae	*Neureclipsis*						
		Polycentropus	2					
	Psychomyiidae	*Lype diversa*						2
	Rhyacophilidae	*Rhyacophila*		3	4	10	10	3
Rhynchobdellida	Glossiphonidae	*Batrachobdella*	1					
Crustacea: Amphipoda	Gammaridae	*Gammarus*						
Decapoda	Cambaridae	*Cambarus*		1				1
Isopoda	Asellidae	*Caecidotea*						
		Lirceus						
Gastropoda: Gastropoda	Pleuroceridae	*Leptoxis*						

Class: Order	Family	Family/Genus	TOML	TOMU	UEBC	UHAR	URRB	WILL	WTDR
Insecta: Coleoptera	**Elmidae**	*Optioservus*		4	17		1	10	
		Oulimnius		2					3
		Promoresia	4				1		10
		Stenelmis							
	Psephenidae	*Psephenus*						1	
		Ectopria					2		
	Ptilodactylidae	*Anchytarsus*	1		1				1
Diptera	**Athericidae**	*Atherix*			10				
	Ceratopogonidae	*Bezzia*							
	Chironomidae	Chironomidae	4		4	15	6		9
	Empididae	*Hemerodromia*							
	Simuliidae	Simuliidae	3					18	
	Tabanidae	*Tabanus*							
	Tipulidae	*Antocha*			1				
		Dicranota			6	1		1	8
		Hexatoma	2			3		3	3
		Limonia					1		
		Tipula		6	1				
Ephemeroptera	**Ameletidae**	*Ameletus*							
	Baetidae	*Acentrella*							
		Baetis			2			2	
		Centroptilum			2				
		Cloeon							2
	Baetiscidae	*Baetisca*							
	Ephemerellidae	*Ephemerella*			7		4		
		Eurylophella							
		Serratella							
	Ephemeridae	*Ephemera*							1
	Heptageniidae	*Epeorus*	1			1			
		Heptagenia							
		Leucrocuta							
		Rhithrogena							
		Stenacron				1			
		Stenonema		1			5	19	
	Isonychiidae	*Isonychia*						30	
	Leptophlebiidae	*Paraleptophlebia*				21	5		2
	Tricorythidae	*Tricorythodes*							
Megaloptera	**Corydalidae**	*Nigronia*	2	6	2		1	5	9
	Sialidae	*Sialis*							
Odonata	**Aeshnidae**	*Boyeria*							1
	Gomphidae	*Lanthus*					2		
		Stylogomphus albistylus						1	
Plecoptera	**Chloroperlidae**	*Alloperla*		2					
		Haploperla							
		Sweltsa							
	Leuctridae	*Leuctra*					2		
	Peltoperlidae	*Peltoperla*							
		Tallaperla		1				3	
	Perlidae	*Acroneuria*	1		3	6	12	1	3
		Agnetina							
		Eccoptura		5					3
		Paragnetina							
	Perlodidae	*Cultus*		1					
		Diploperla							
		Hydroperla							6
		Isoperla						1	
		Remenus							
	Pteronarcyidae	*Pteronarcys*	1			1			2
	Taeniopterygidae	*Strophopteryx*	1			7			
		Taeniopteryx							

Class: Order	Family	Family/Genus	TOML	TOMU	UEBC	UHAR	URRB	WILL	WTDR
Trichoptera	Brachycentridae	*Brachycentrus*							4
	Glossosomatidae	*Agapetus*							
		Glossosoma			4		5	1	
		Protoptila							
	Hydropsychidae	*Cheumatopsyche*	4	4	7	14	7	5	9
		Diplectrona	3	1	2		2		
		Homoplectra		4					
		Hydropsyche	2		23	5	3	3	4
		Potamyia flava		4		11	2		
	Lepidostomatidae	*Theliopsyche*				1			
	Odontoceridae	*Psilotreta*							3
	Philopotamidae	*Chimarra*					19	1	4
		Dolophilodes	2	1	13	11	16	2	16
	Polycentropodidae	*Neureclipsis*							
		Polycentropus							
	Psychomyiidae	*Lype diversa*		3					
	Rhyacophilidae	*Rhyacophila*		1		2	1	2	5
Rhynchobdellida	Glossiphonidae	*Batrachobdella*	1						
Crustacea: Amphipoda	Gammaridae	*Gammarus*							
Decapoda	Cambaridae	*Cambarus*	2	1					
Isopoda	Asellidae	*Caecidotea*							
		Lirceus							
Gastropoda: Gastropoda	Pleuroceridae	*Leptoxis*						1	